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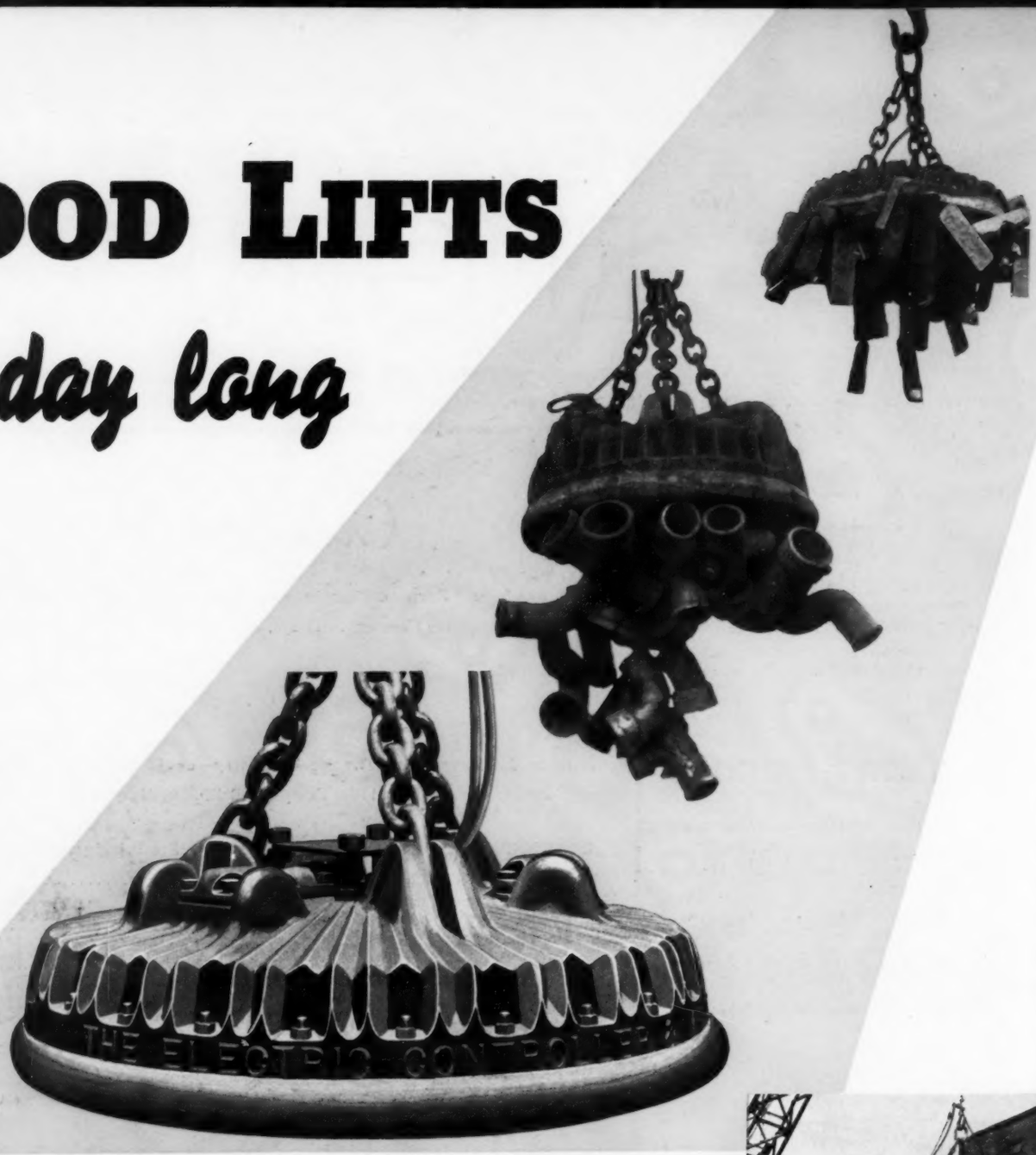

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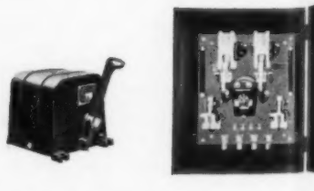

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VALUE OF A CONVENTION

MEETINGS to expound a theory, present a project, disclose an improvement or to discuss a political, religious or public subject have always been a very helpful and stimulating influence in our every day lives, domestic, business and otherwise.

It is true however that the effectiveness and value of meetings are often greatly limited by restraint and lack of free and frank presentation and discussion of the subject.

Not many years ago, it was the accepted view that a public discussion of one's business methods and the technical details and merits of products offered was a rather questionable policy and as a result such discussions were approached in rather guarded manner and largely limited to generalities.

One of the most helpful and progressive principles which gave the founders of the Association of Iron and Steel Engineers (then the Association of Iron and Steel Electrical Engineers) their faith in the Association's ability to accomplish something worth while and encouraged their efforts was the belief that the advancement of engineering could be accomplished by co-operation of its members. As a result of the methods pursued and programs followed a free interchange of ideas and a frank discussion of each others problems was soon the order of the day.

As the Association's activities progressed, the proper technic of procedure became more and more apparent. As soon as the engineers were better informed by interchange of experiences and ideas the more able they were to formulate their engineering ideas and present their problems to the machinery manufacturers. The more information these men secured about operating conditions and objectives sought by the steel industry the better able they were to design improved machinery for advancement of the art of manufacturing and rolling steel.

Fundamentally one of the greatest indirect contributions the Association has made to the steel industry is the feeling of confidence and the helpful spirit they developed between the steel engineers and other engineers. This factor stimulated and directly assisted one of the most important and effective engineering achievements of the industry, namely its practically universal electrification.

The National Meeting held in Youngstown, Ohio, February 25th, included a technical discussion of three interesting steel mill subjects namely, "Industrial Furnace Design", "Application of the Ward Leonard Control for Blooming Mill Auxiliary Drives" and "Continuous Rolling of Strip Steel". As is indicated by this program all phases of steel mill engineering is included in the Association's activities. More than 750 steel men attended the meeting and enjoyed the privilege of a visit to the Hot and Cold Strip Mill of the Youngstown Sheet and Tube Company.

The SPRING CONFERENCE of the Association scheduled for Buffalo, N.Y., April 28 and 29 offers another opportunity for the technical discussion of the newer and better practices and equipment for the steel industry. Thus to further the idea that the Association's activities lead to advancement by co-operation of its members, we urge that you make your plans now to attend this meeting.

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A Study of BLAST FURNACE CHARGING

By GORDON FOX, Vice President
Freyn Engineering Co.
CHICAGO, ILLINOIS

Presented before the Annual Convention of the A. I. & S. E., Detroit, Michigan, Sept. 22-25, 1936

▲ IT is not the intent of this paper to deal with questions concerning blast furnace burdening, distribution and consequent furnace performance. It merely deals with the mechanics of material handling to meet the more or less prescribed specifications in a particular case.

GORDON FOX

Our remarks will relate principally to a study which was made in cooperation with Gipromez as a phase of the design of the 1000-ton standard blast furnace which now finds a place in most of the new Russian steel plants. It is attempted to present only enough of the study to illustrate the procedure used, to indicate some of the conclusions reached, and to show some of the reasons for the decisions made.

It is not intimated that the practices determined upon in this instance should be applied categorically in America. However, it is thought that the outline of this one study, together with the attendant remarks, parallels sufficiently closely American practice to warrant its presentation.

During our school-days we used to enjoy the practice of looking in the back of the book to know the answer before we undertook the problem. In somewhat the same manner I will describe briefly the character and the principal dimensions of the charging equipment which was finally chosen. I will then show some portions of the study of charging schedules premised on this combination of equipment and which indicate the degree of adequacy thereof.

The basis of design is a skip tub of rather large volumetric capacity, namely, 6 cu. m. or 212 cu. ft. If filled to capacity, the contents of this skip tub represent approximately one foot depth at the furnace stockline. Thus a coke charge of two full skips has an average depth of about two feet, while three full skips of coke will give an average depth of about three feet. Such coke charges were considered to be the basis for satisfactory charging rounds. It may be noted, however, that there is sufficient leeway in charging time to permit the use of somewhat reduced coke charges which may not completely fill the skips, in the event that any operating advantage, temporary or otherwise, might accrue from such practice. In other words, a large skip tub volume *permits* the use of a liberal coke charge but it may not *necessitate* it.

The skip hoist is of the normal, balanced type using two skip tubs with bails. The skip engine is of single drum type and is located in a hoist house at cast house elevation and directly beneath the skip incline. The length of the skip trip, with standard layout, is 207 ft. The rope speed, as finally selected, is 1¾ met. per sec.,or about 330 ft. per min. The total time of a trip, including acceleration and deceleration periods, is about 47 seconds.

The small bell hopper has a capacity somewhat in excess of that of the skip tub. It is arranged with revolving distributor of six-position type, the 60-120-180 degree positions being reached by forward rotation, while the 240 and 300 deg. positions are reached by reverse rotation. The distributor is geared to make a trip of 180 deg. in about 16 seconds.

The large bell hopper has a capacity to accommodate a charge up to 21 m^3, or about 750 cu. ft. This is sufficient to permit a full charge, comprising two skips of coke and the corresponding ore and stone quantities, to be carried on the large bell before dumping, should such procedure be desired. A charge based on three coke skips cannot be so carried. It is anticipated that, in normal operation, the large bell will be operated twice during a round, once to discharge coke and once to discharge ore, stone and associated materials.

The bells are suspended from rods and chains which depend from sectors of the bell levers. The bell levers

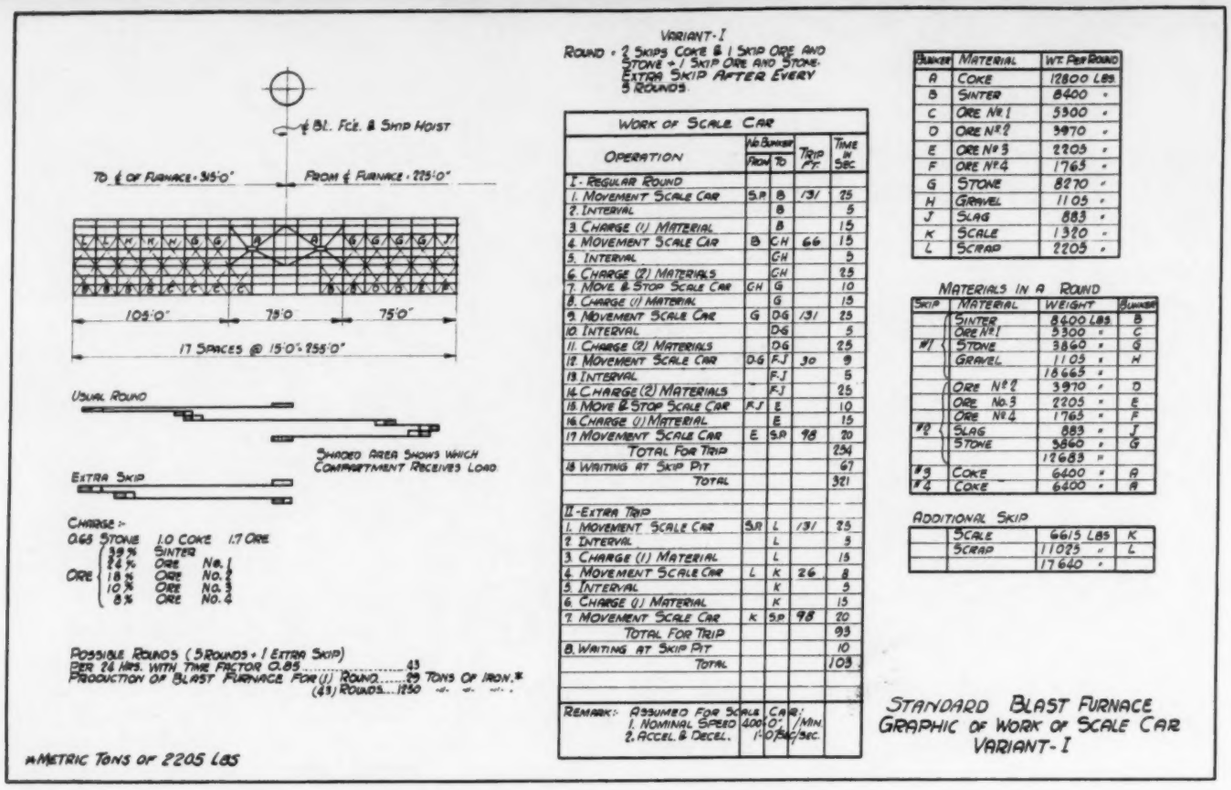

VARIANT-I
ROUND = 2 SKIPS COKE & 1 SKIP ORE AND STONE + 1 SKIP ORE AND STONE. EXTRA SKIP AFTER EVERY 5 ROUNDS.
℄ BL. FCE. & SKIP HOIST
TO ℄ OF FURNACE = 315'0"
FROM ℄ FURNACE = 225'0"
105'0"
75'0
75'0"
17 SPACES @ 15'0" = 255'0"
USUAL ROUND
SHADED AREA SHOWS WHICH COMPARTMENT RECEIVES LOAD
EXTRA SKIP
CHARGE :-
0.65 STONE 1.0 COKE 1.7 ORE
39% SINTER
24% ORE No. 1
18% ORE No. 2
10% ORE No. 3
8% ORE No. 4
POSSIBLE ROUNDS (5 ROUNDS + 1 EXTRA SKIP) PER 24 HRS. WITH TIME FACTOR 0.85 43
PRODUCTION OF BLAST FURNACE FOR (1) ROUND ..... 29 TONS OF IRON.*
(43) ROUNDS 1250
*METRIC TONS OF 2205 LBS
WORK OF SCALE CAR
OPERATION | NO. BUNKER FROM | NO. BUNKER TO | TRIP PT. | TIME IN SEC.
I- REGULAR ROUND
1. MOVEMENT SCALE CAR | S.P. | B | 131 | 25
2. INTERVAL | | B | | 5
3. CHARGE (1) MATERIAL | | B | | 15
4. MOVEMENT SCALE CAR | B | C-H | 66 | 15
5. INTERVAL | | C-H | | 5
6. CHARGE (2) MATERIALS | | C-H | | 25
7. MOVE & STOP SCALE CAR | C-H | G | | 10
8. CHARGE (1) MATERIAL | | G | | 15
9. MOVEMENT SCALE CAR | G | D-G | 131 | 25
10. INTERVAL | | D-G | | 5
11. CHARGE (2) MATERIALS | | D-G | | 25
12. MOVEMENT SCALE CAR | D-G | F-J | 30 | 9
13. INTERVAL | | F-J | | 5
14. CHARGE (2) MATERIALS | | F-J | | 25
15. MOVE & STOP SCALE CAR | F-J | E | | 10
16. CHARGE (1) MATERIAL | | E | | 15
17. MOVEMENT SCALE CAR | E | S.P. | 98 | 20
TOTAL FOR TRIP | | | | 254
18. WAITING AT SKIP PIT | | | | 67
TOTAL | | | | 321
II-EXTRA TRIP
1. MOVEMENT SCALE CAR | S.P. | L | 131 | 25
2. INTERVAL | | L | | 5
3. CHARGE (1) MATERIAL | | L | | 15
4. MOVEMENT SCALE CAR | L | K | 26 | 8
5. INTERVAL | | K | | 5
6. CHARGE (1) MATERIAL | | K | | 15
7. MOVEMENT SCALE CAR | K | S.P. | 98 | 20
TOTAL FOR TRIP | | | | 93
8. WAITING AT SKIP PIT | | | | 10
TOTAL | | | | 103
REMARK:- ASSUMED FOR SCALE CAR; 1. NOMINAL SPEED 400'-0"/MIN. 2. ACCEL. & DECEL. 1'-0"/SEC/SEC.
BUNKER | MATERIAL | WT PER ROUND
A | COKE | 12800 LBS
B | SINTER | 8400 "
C | ORE No. 1 | 5300 "
D | ORE No. 2 | 3970 "
E | ORE No. 3 | 2205 "
F | ORE No. 4 | 1765 "
G | STONE | 8270 "
H | GRAVEL | 1105 "
J | SLAG | 883 "
K | SCALE | 1320 "
L | SCRAP | 2205 "
MATERIALS IN A ROUND
SKIP | MATERIAL | WEIGHT | BUNKER
#1 | SINTER | 8400 LBS | B
#1 | ORE No. 1 | 5300 " | C
#1 | STONE | 3860 " | G
#1 | GRAVEL | 1105 " | H
#1 | | 18665 " |
#2 | ORE No. 2 | 3970 " | D
#2 | ORE No. 3 | 2205 " | E
#2 | ORE No. 4 | 1765 " | F
#2 | SLAG | 883 " | J
#2 | STONE | 3860 " | G
#2 | | 12683 " |
#3 | COKE | 6400 " | A
#4 | COKE | 6400 " | A
ADDITIONAL SKIP
SCALE | 6615 LBS | K
SCRAP | 11025 " | L
| 17640 " |
STANDARD BLAST FURNACE GRAPHIC OF WORK OF SCALE CAR VARIANT-I

Figure 1—Study of scale car movements.

are only moderately counterweighted. The bells are held in closed position by downward pull of the cables at the extremities of the levers. The bells are operated by low pressure air cylinders which hold the bell closed partly by their weight but principally due to air pressure acting downwardly. The air valves which actuate the air cylinders are motor-operated and are governed by the automatic charging control. The bells will normally be timed about as follows:

	Open	Pause	Close	Total
Small bell.....	8 sec.	4 sec.	8 sec.	20 sec.
Large bell.....	12 sec.	6 sec.	12 sec.	30 sec.

The time of the bell movements can be controlled, within limits, by adjustment of valves in the air supply and air discharge lines, and the pause can be varied by adjustment of the automatic charging control.

The furnace is provided with two stockline measuring devices of the continuous recording type, oppositely located. These are motor-operated and their control is a part of the automatic charging system.

The scale car has two compartments, each having a volumetric capacity corresponding to the skip tub capacity. The discharge gates are operated by high pressure air cylinders and controlled by manually-operated valves in series with solenoid-operated valves which permit opening a gate only when the solenoid is actuated. These solenoids are energized through short sections of collector rail located only at the skip pit. The control for the solenoids is tied in with the automatic charging control in such manner that the scale car compartments can be discharged only under proper conditions.

The scale car is motored and geared to have a free running or maximum speed of 120m per min., or about 400 ft. per min.

The bins are arranged in a double row with two central coke bins. The general arrangement is shown in Figure 1. The coke bins are provided with weigh-hoppers which are arranged for automatic weighing and charging of the coke. The other bins are provided with roller type gates which are actuated by a motor on the scale car.

As a first step in our analysis of charging operations we will consider the movements of the scale car. These movements are diagrammed in Figures 1, 2 and 3. Three variants are shown. Many other variants are possible of course. The variants shown are not exceptionally favorable. They may be considered as representative or rather unfavorable. Simplification is possible, particularly with respect to charging the several varieties of ore on separate trips rather than all varieties on each trip, as indicated.

The time required for scale car movements over various distances is determined from the velocity-time curves shown in Figure 4. These curves are derived on the premises of an initial accelerating rate of about 1 ft. per sec. per sec., and a similar rate in braking. The time required for weighing and charging the scale car

is based on experience. Because of the impossibility in attaining perfection in coordinating scale car operations, a number of short intervals have been arbitrarily interposed.

The principal data resulting from these studies may be presented in tabular form:

TABLE I
TIME OF SCALE CAR MOVEMENTS

Variant	Description of Round	Total Time of First Movement	Total Time of Second Movement
1	2 skips of coke 1 skip ore and stone–. 1 skip ore and stone–.	254 sec.	None
2	2 skips of coke..... 2 skips of ore..... 1 skip of stone.....	214 sec.	128 sec.
3	3 skips of coke..... 2 skips of ore..... 1 skip of stone.....	220 sec.	165 sec.

In Variant 1, the scale car makes one trip, filling both compartments (254 sec.). In Variants 2 and 3, it makes one trip, filling both compartments (214 and 220 sec.), and one trip in which only one compartment is filled (128 and 165 sec.).

With this background of scale car operation we may now proceed to consider how the several charging operations coordinate and how their time requirements are related, one to another. These relationships can be analyzed most readily by diagrams such as are shown on Figs. 5-6-7. These three diagrams refer to three different charging rounds, corresponding to the scale car movements shown in Figs. 1-2-3.

Let us first consider the round shown in Fig. 5. This round, as plotted, consists of two skips of coke followed by two skips each containing ore and stone. The chart begins at the point where the scale car has discharged its second compartment and has started the skip loaded therefrom to ascend. The scale car then proceeds to the bins to take on another charge.

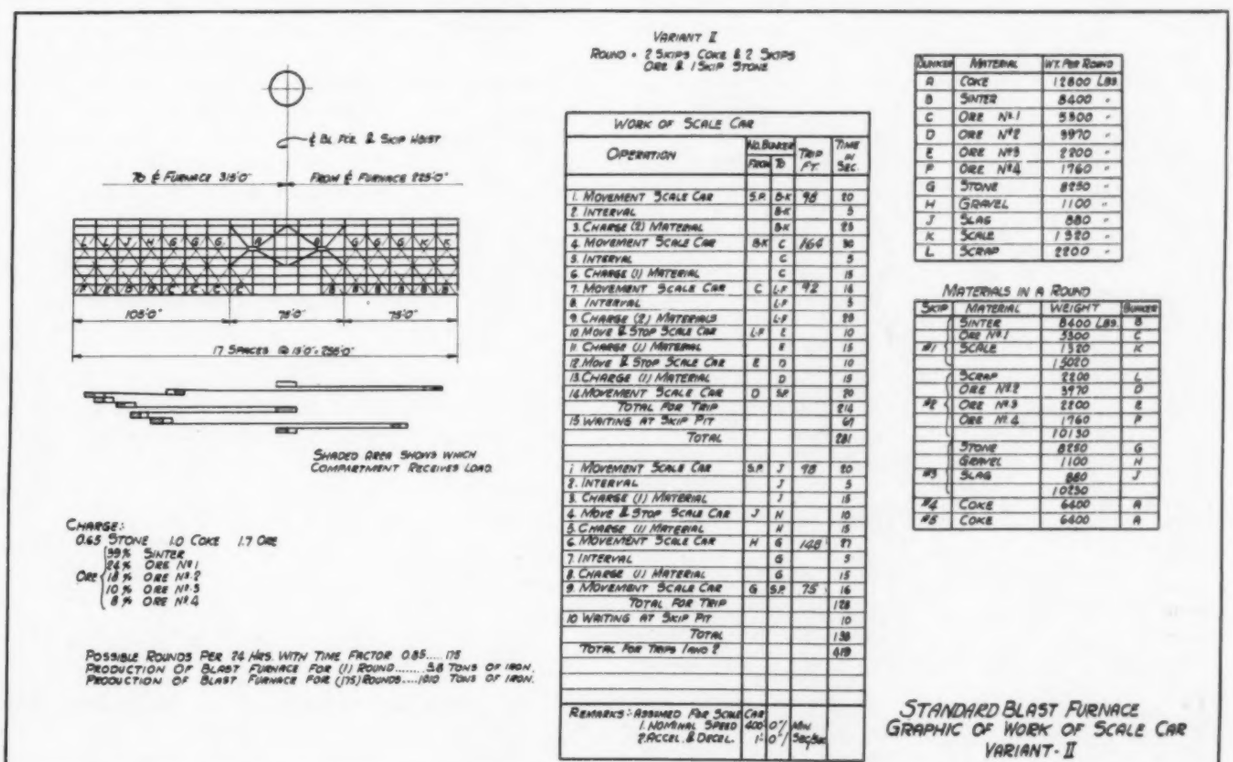
While the skip of ore and stone is discharging at the top of the furnace, the other skip is automatically loaded with coke in the skip pit. As soon as this operation is completed (by the coke hopper becoming empty), the skip now loaded with coke starts to ascend. At the same time the small bell is lowered, discharged and closed. No time is required for rotation of the hopper, which happens to be at the zero position.

Since a round has just been completed, the large bell must also be discharged. To minimize the time required for this operation, the stockline rods are withdrawn simultaneously with closure of the small bell. They are again lowered while the large bell is closing. As indicated, the large bell does not complete its cycle before the skip of coke reaches the furnace top but it is closed several seconds before the small bell, carrying that coke load, is lowered.

While this first skip of coke has been ascending, the coke hopper has automatically filled and is ready to be discharged to a later skip.

When the first skip of coke arrives at the furnace top it is discharged during the interval while the second skip of coke is being loaded in the skip pit. When the

Figure 2—Study of scale car movements.


VARIANT II
ROUND = 2 SKIPS COKE & 2 SKIPS ORE & 1 SKIP STONE
WORK OF SCALE CAR
MATERIALS IN A ROUND
STANDARD BLAST FURNACE
GRAPHIC OF WORK OF SCALE CAR
VARIANT - II

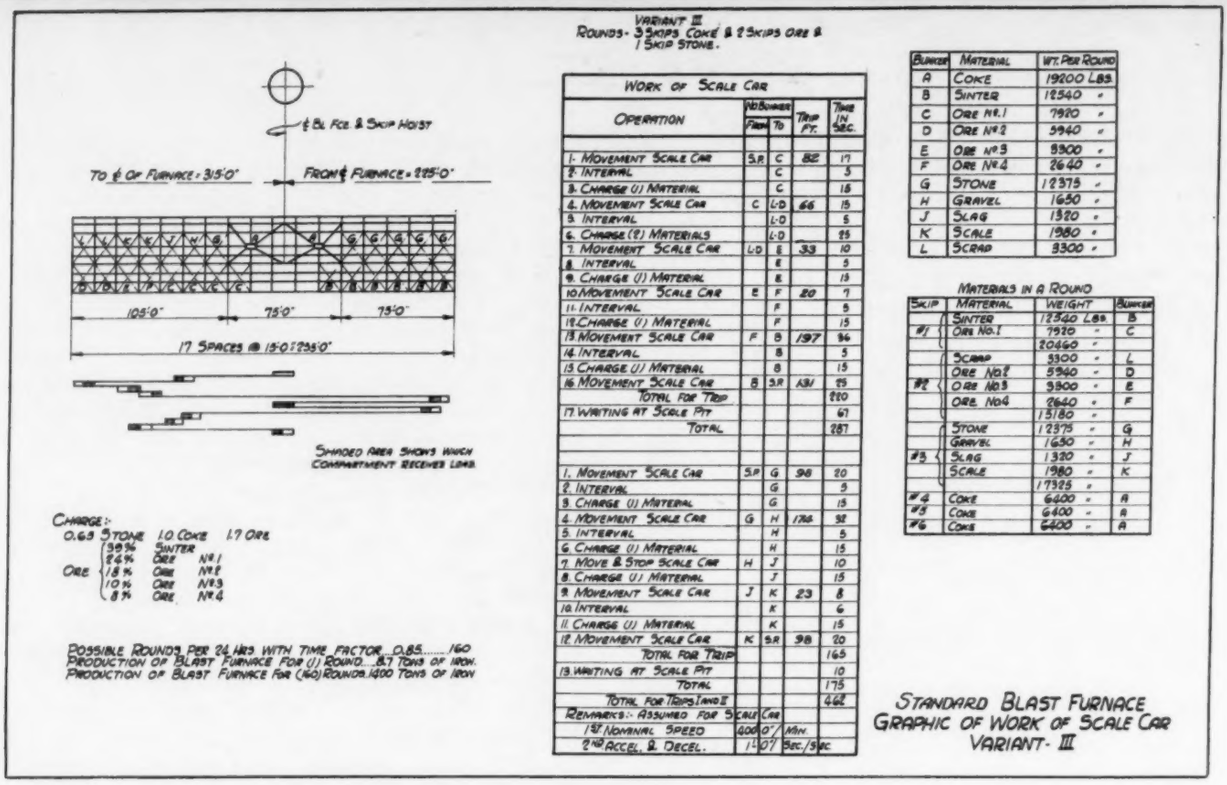

VARIANT III
ROUNDS- 3 SKIPS COKE & 2 SKIPS ORE & 1 SKIP STONE.
℄ BL. FCE. & SKIP HOIST
TO ℄ OF FURNACE = 315'0"
FRONT ℄ FURNACE = 225'0"
105'0"
75'0"
75'0"
17 SPACES @ 15'0" = 255'0"
SHADED AREA SHOWS WHICH COMPARTMENT RECEIVES LOAD.
CHARGE:
0.63 STONE 1.0 COKE 1.7 ORE
ORE 39% SINTER
24% ORE NO.1
18% ORE NO.2
10% ORE NO.3
8% ORE NO.4
POSSIBLE ROUNDS PER 24 HRS WITH TIME FACTOR 0.85 160
PRODUCTION OF BLAST FURNACE FOR (1) ROUND ..8.7 TONS OF IRON.
PRODUCTION OF BLAST FURNACE FOR (160) ROUNDS 1400 TONS OF IRON
WORK OF SCALE CAR
OPERATION | NO. BUNKERS FROM | TO | TRIP FT. | TIME IN SEC.
1. MOVEMENT SCALE CAR | S.R. | C | 82 | 17
2. INTERVAL | | C | | 5
3. CHARGE (1) MATERIAL | | C | | 18
4. MOVEMENT SCALE CAR | C | L-D | 66 | 15
5. INTERVAL | | L-D | | 5
6. CHARGE (2) MATERIALS | | L-D | | 25
7. MOVEMENT SCALE CAR | L-D | E | 33 | 10
8. INTERVAL | | E | | 5
9. CHARGE (1) MATERIAL | | E | | 13
10. MOVEMENT SCALE CAR | E | F | 20 | 7
11. INTERVAL | | F | | 5
12. CHARGE (1) MATERIAL | | F | | 15
13. MOVEMENT SCALE CAR | F | B | 197 | 56
14. INTERVAL | | B | | 5
15. CHARGE (1) MATERIAL | | B | | 15
16. MOVEMENT SCALE CAR | B | S.R. | 431 | 95
TOTAL FOR TRIP | | | | 220
17. WAITING AT SCALE PIT | | | | 67
TOTAL | | | | 287
1. MOVEMENT SCALE CAR | S.P. | G | 98 | 20
2. INTERVAL | | G | | 5
3. CHARGE (1) MATERIAL | | G | | 15
4. MOVEMENT SCALE CAR | G | H | 176 | 32
5. INTERVAL | | H | | 5
6. CHARGE (1) MATERIAL | | H | | 15
7. MOVE & STOP SCALE CAR | H | J | | 10
8. CHARGE (1) MATERIAL | | J | | 15
9. MOVEMENT SCALE CAR | J | K | 23 | 8
10. INTERVAL | | K | | 6
11. CHARGE (1) MATERIAL | | K | | 15
12. MOVEMENT SCALE CAR | K | S.R. | 98 | 20
TOTAL FOR TRIP | | | | 165
13. WAITING AT SCALE PIT | | | | 10
TOTAL | | | | 175
TOTAL FOR TRIPS I AND II | | | | 462
REMARKS:- ASSUMED FOR SCALE CAR
1ST NOMINAL SPEED 600'0" / MIN.
2ND ACCEL. & DECEL. 1.407 SEC./SEC.
BUNKER | MATERIAL | WT. PER ROUND
A | COKE | 19200 LBS.
B | SINTER | 12540 "
C | ORE NO.1 | 7920 "
D | ORE NO.2 | 5940 "
E | ORE NO.3 | 9900 "
F | ORE NO.4 | 2640 "
G | STONE | 12375 "
H | GRAVEL | 1650 "
J | SLAG | 1320 "
K | SCALE | 1980 "
L | SCRAP | 3300 "
MATERIALS IN A ROUND
SKIP | MATERIAL | WEIGHT | BUNKER
#1 | SINTER | 12340 LBS. | B
#1 | ORE NO.1 | 7930 " | C
#1 | | 20460 " |
#2 | SCRAP | 3300 " | L
#2 | ORE NO.2 | 5940 " | D
#2 | ORE NO.3 | 9900 " | E
#2 | ORE NO.4 | 2640 " | F
#2 | | 15180 " |
#3 | STONE | 12375 " | G
#3 | GRAVEL | 1650 " | H
#3 | SLAG | 1320 " | J
#3 | SCALE | 1980 " | K
#3 | | 17325 " |
#4 | COKE | 6400 " | A
#5 | COKE | 6400 " | A
#6 | COKE | 6400 " | A
STANDARD BLAST FURNACE
GRAPHIC OF WORK OF SCALE CAR
VARIANT- III

Figure 3—Study of scale car movements.

second skip of coke starts to ascend, the hopper starts ro revolve. When it reaches the 60 degree position, the small bell is lowered, discharged and closed.

When the second skip of coke reaches the furnace top, it discharges. After a suitable time interval, shown as 10 seconds, the hopper revolves but the small bell does not function until the next skip movement is initiated.

The charging of the two skips of coke has been completed in about 125 seconds, or at the point of time indicated as 175. Charging operations now await the return of the scale car. As previously indicated, this takes place after an absence of 254 seconds. Upon arrival at the skip pit, the scale car proceeds to discharge the two compartments thereof in sequence and again proceeds as before.

The total time of one round is shown as 321 seconds. The time for five such rounds is 1,605 seconds. After every fifth round an extra skip containing scale and scrap is sent up at the end of the round. This may be done without disturbing the sequencing of the charging control. The time for five rounds is thus increased to 1,703 seconds. Allowing an operating time factor of 85 per cent, or 1,220 minutes per day, thus allowing two hours for delays or idle periods, the charging cycle shown is indicated to have a potential production capacity of 1,250 tons of iron per day. Viewed in another way, for a production of 1,000 tons iron per day, charging must proceed according to schedule during 980 minutes out of 1,440 minutes, or about 70 per cent of the time.

These figures refer to potential iron production based on the premise that one ton of coke is required per ton of iron produced. This is a conservative premise. In the event of a lower coke rate, larger mounts of ore would be charged to correspond with the same coke charges. This is possible since the volumetric capacity of the scale car, skip tub and small bell hopper are not fully utilized for normal ore and stone charges. Thus, if the coke rate were 0.85 (1,870 lb. per metric ton of 2,205 lb. of iron), Variant 1 has a potential capacity in 1,220 minutes of 1,470 tons of iron per day and the charging for 1,000 tons iron can be accomplished in 835 minutes, or about 58 per cent of the available time.

Figures 6 and 7 show the conditions applying to two other variants corresponding to the scale car movements scheduled in Figures 2 and 3. The resultant figures for several variants are shown in Table II. An inspection of these figures indicate that with the charging methods or variants shown. the furnace can be charged to produce 1,000 tons per 24 hours, with a coke ratio of 1.0, the charging operations requiring from about 60 to 85 per cent of the total time. With a coke ratio of 0.85, charging operations for a production of 1,000 tons require about 52 to 72 per cent of the total time.

These figures refer to the results obtainable with a skip hoist speed of 330 ft. per min. The table also indicates what results may be expected from the same charging methods with a skip hoist speed of 2.5 meters per sec., or about 500 ft. per min. It is rather striking that although the skip hoist speed is increased 50 per cent, the increase in potential production is only about 5 per cent. The reason for this results become evident through inspection of the diagrams in Figures 5-6-7. No gain in time results through increase in the speed of the skips carrying coke (provided a round does not include more than three skips), because even with the slower speed these skips can be sent up while the scale car is filling at the bins and the coke charging can be

completed before the scale car returns. Only at one point does the increased skip speed have an effect, namely, after the first compartment of the scale car has been emptied and while the scale car waits at the skip pit for the arrival of the other skip. At this point the faster skip saves some 10 or 15 seconds time. A saving of this small amount in a round involving a total time on the order of 400 seconds, is not significant.

A further study of the diagrams in Figures 5-6-7 indicates that a high skip speed may be undesirable not only because the skip movements are faster than the scale car movements, but also because the skip movements become too fast for the furnace top mechanisms. At several points in diagrams 5-6-7, dotted lines are drawn at points 7 sec. before the end of the skip travel. The dotted line represents the point at which the skip should be stopped, as it starts over the knee of the incline, provided the small bell has not lowered, discharged and fully closed. It will be noted that when the small bell hopper is rotating 120 or 180 degrees the small bell completes its cycle just in time to permit the skip to complete its trip without interruption. If the skip speed were increased, the skip would reach this slow-down point before the small bell was closed. The skip should then be stopped to prevent discharge upon a partly-open small bell. This would happen quite frequently. This would largely nullify any benefit accruing from the increased skip speed.

It may be noted also that if the skip speed were materially increased there would be a paucity of time available for the functioning of the small bell at those points where the large bell must complete its cycle before the small bell can initiate its action. (Note Fig. 7 at time 1510 seconds.)

These studies indicate the following relation. The skip hoist is but an intermediate element in a complex charging operation. Increase in skip speed may have but a negligible effect on overall results. It is essential that the skip movements and those at the bins and at the furnace top be coordinated and properly related so that no one part of the charging mechanism functions faster than the other parts upon which it is dependent.

It may be argued, in this connection, that the speeds of all the mechanisms considered in this case are low, and that these speeds might be increased, thereby permitting a somewhat increased skip speed. This is true. This entire design is premised on the theorem that if moderate speed movements properly coordinated afford adequate performance, there can be little justification for high speeds. These mechanisms are large and involve heavy masses; their operation is of start and stop character; inertia is an important consideration. Kinetic energy must be imparted during acceleration and must be dissipated during deceleration with every movement. Smoother, simpler operation, less impact stresses, lower power consumption and less maintenance cost are inherent in the slower speed mechanisms. Speed, where unnecessary, is distinctly a liability.

Let us consider what speed may mean in the first

TABLE II

Tabulation—Summary of tonnage possibilities and time requirements for 1000-ton production.

Variant	Description of Round	Capacity at 1.0 Coke Ratio				Capacity at 0.85 Coke Ratio			
		Skip speed 330 ft./min.		Skip speed 500 ft./min.		Skip speed 330 ft./min.		Skip speed 500 ft./min.	
		Tons in 1220 min. charging	% time charging for 1000 tons	Tons in 1220 min. charging	% time charging for 1000 tons	Tons in 1220 min. charging	% time charging for 1000 tons	Tons in 1220 min. charging	% time charging for 1000 tons
1	2 skips of coke 2 skips of ore and stone	1250	70	1315	65	1470	58	1550	54
2	2 skips of coke 2 skips of ore 1 skip of stone	1010	84	1050	81	1190	71	1230	69
3	3 skips of coke 2 skips of ore 1 skip of stone	1400	61	1445	59	1650	52	1710	50
4	2 skips of coke 2 skips of ore 2 skips of coke 2 skips of ore 1 skip of stone	1190	72	1260	68	1400	61	1480	57

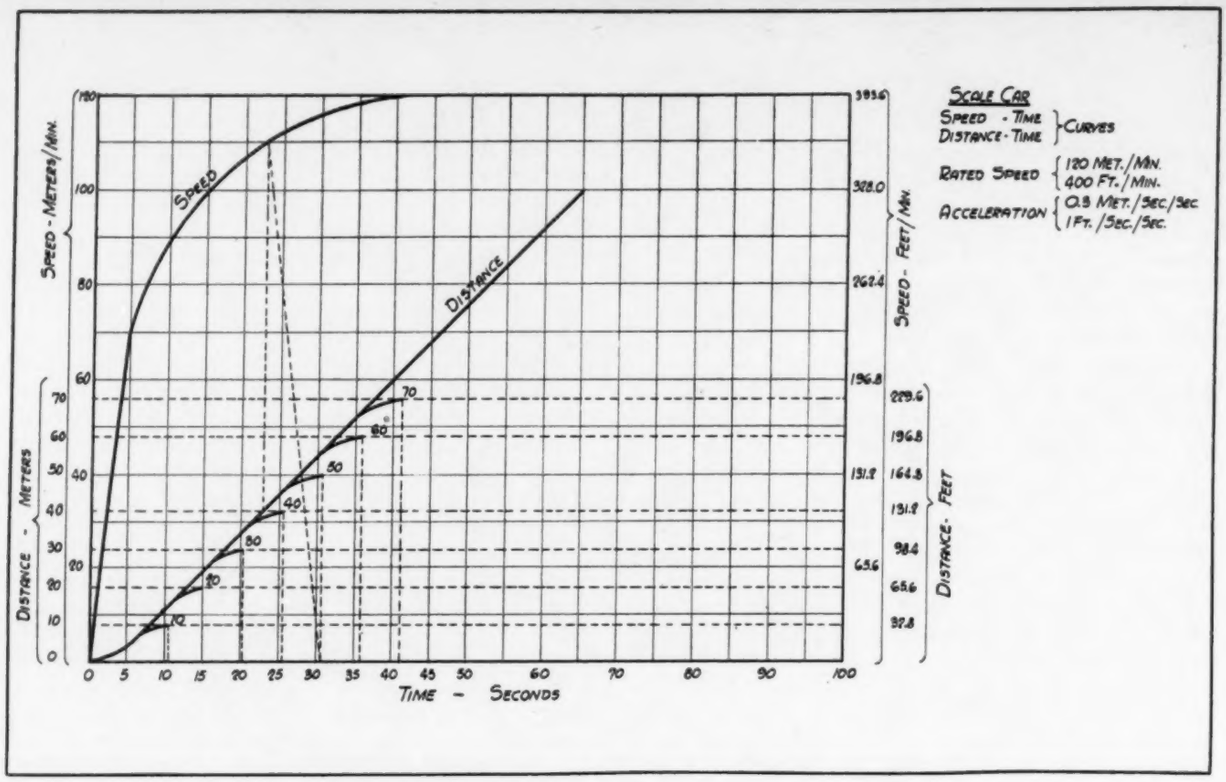


Figure 4—Speed-time and distance-time curves for scale car.

cost of the skip hoist drive. Table III is of interest in this connection. For the skip speed of 330 ft. per min., a simple compound-wound motor drive is employed. The ratio of free-running speed to slow-down speed is about 330/80, or about 4 to 1. Such a speed ratio can be obtained economically and entirely satisfactorily with this type of drive. Since the skip hoist is supplied from the 250 volt direct-current system, which also supplies the ore bridges, unloaders and other furnace equipment, the motor-generator set capacity required is minimized due to diversity.

For skip speeds of 400 and 500 ft. per min. it was considered that the Ward-Leonard type of drive would be preferable. Such a drive requires a self-sufficient motor-generator set. As the same hoisting work is concentrated into a shorter period, the load is correspondingly increased. An appreciable part is played by kinetic energy. The inertia of the load, referred to the motor shaft, associated with the drive at 500 ft. per min. is about three times that associated with a speed of 300 ft. per min. The size of drive motor required is substantially affected. It is indicated in the table that the amount and cost of the electrical equipment is nearly twice as great for a skip speed of 500 ft. per min. as for a skip speed of 300 ft. per min.

The cost of electrical equipment is not the only cost consideration. If the same accelerating period is allowed, the rope pull associated with the high speed

TABLE III

Tabulation—Comparison of electrical equipment for skip hoists.

Skip Speed		Mechanical Load on Motor*								Total installed kw.	Approx. Cost of electrical equipment
meters sec.	ft. min.	Free running		Accelerating		Hoist	Motor	M.G. Set			
		hp.	kw.	hp.	kw.	hp.	kw.	Gen. kw.	Mlt. kw.		
1.5	300	280	210	315	234	250	188	125	145	458	$11,200
2.0	400	370	278	416	312	335	250	290	340	880	17,300
2.5	500	465	350	520	390	400	300	350	400	1050	21,700

*These figures apply to the maximum condition with skip filled with ore. Under usual operating conditions the load will be less.

hoist is substantially greater. For equal safety factors, larger cables are required. This in turn means larger sheaves. And because of the heavier impact stresses associated with high speed operation, the skip incline requires substantial reinforcement.

In view of adequacy in charging capacity with moderate speed equipment, indicated by the several studies made, it was decided that for this design the use of high-speed equipment was unnecessary and could not be justified.

It will have been noted that the charging schedules indicated in diagrams 5-6-7 all contemplate that coke be charged during the period while the scale car is away from the skip pit and is engaged in loading at the bins. If this were not done, much of the time of the scale car would be wasted in standing at the skip pit while coke is charged. This would seriously restrict the capacity of the whole charging system. To attempt to compensate for such waste of time by speeding up the charging mechanisms would be to tackle the problem in a left-handed manner. Independent coke charging can be accomplished by assigning an extra man to operate the coke charging movements and other operations manually. It can also be accomplished by automatic charging of coke. For the Gipromez standard furnaces the latter method, based on coke weighing, was preferred.

Automatic coke weighing and full-automatic charging were adopted principally for the following reasons:*

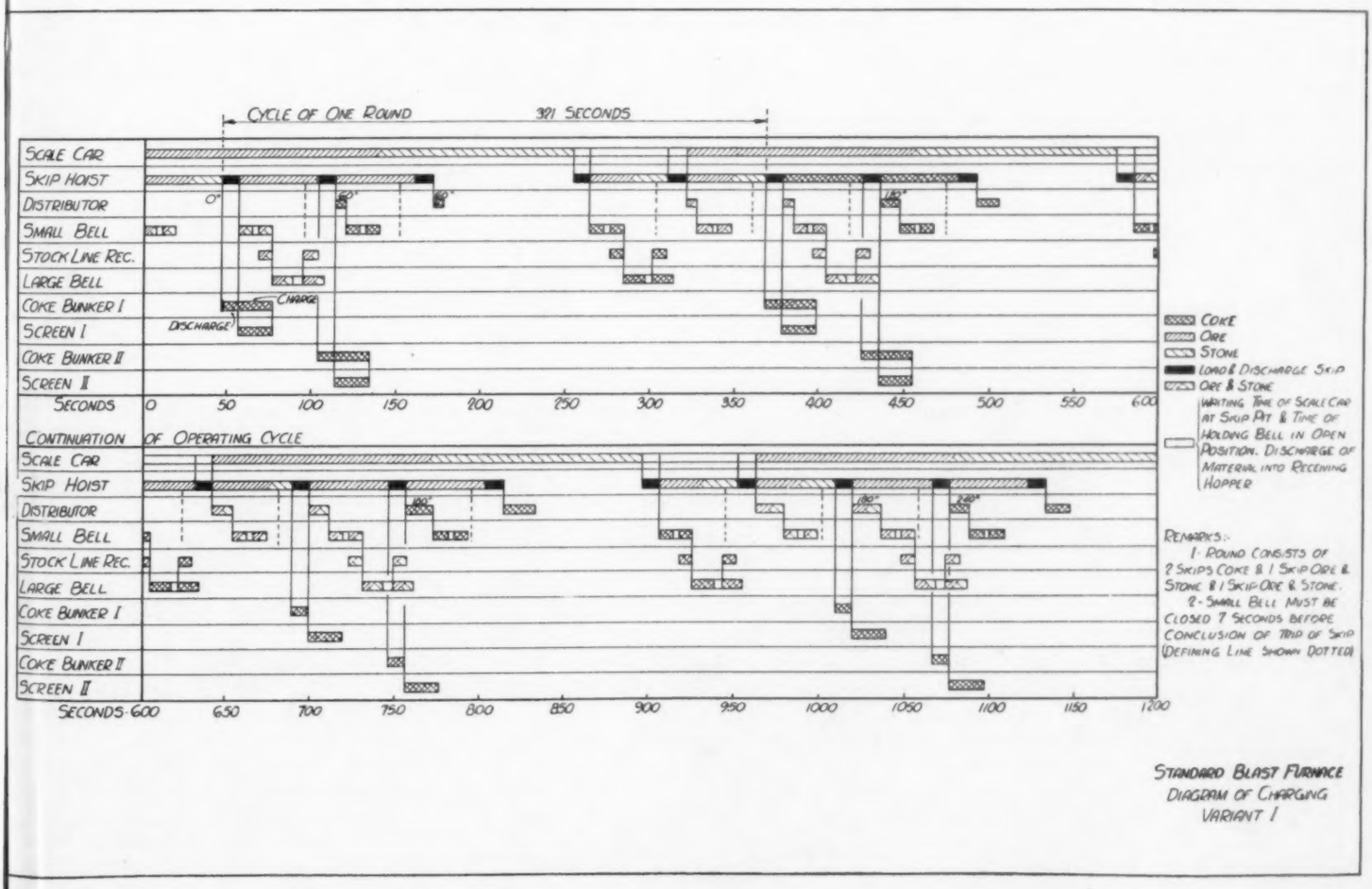
1. Best possible coordination of equipment movements, permitting maximum charging performance with minimum speeds. Automatic coordination is substantially better than can be expected with manual control.
2. Greatest possible accuracy of charging through minimizing chances for human error.
3. Forced sequencing, which eliminates messes and pile-ups by interlocking which requires that every movement be preceded by completion of the next prior dependent movement, and which prevents initiation of any action except under proper circumstances.
4. Greater accuracy of coke charges.
5. Minimum operating labor and operating cost.
6. Minimum first cost.

One other feature of the design is deserving of comment, namely, the mode of bell operation. Bell hoists may be considered as of two broad types, illustrated in Figure 8.

1. Those in which the bell lever is fully counterweighted and an upward pull is required to lift the counterweight in order to lower the bell. The upward pull may be obtained by steam or

*Substantially the same results can be obtained with automatic coke charging arranged for automatic measurement of volume rather than of weight.

Figure 5—Time study of all charging operations.


CYCLE OF ONE ROUND
321 SECONDS
SCALE CAR
SKIP HOIST
DISTRIBUTOR
SMALL BELL
STOCK LINE REC.
LARGE BELL
COKE BUNKER I
SCREEN I
COKE BUNKER II
SCREEN II
SECONDS
CHARGE
DISCHARGE
CONTINUATION OF OPERATING CYCLE
COKE
ORE
STONE
LOAD & DISCHARGE SKIP
ORE & STONE
WAITING TIME OF SCALE CAR AT SKIP PIT & TIME OF HOLDING BELL IN OPEN POSITION. DISCHARGE OF MATERIAL INTO RECEIVING HOPPER
REMARKS:-
1- ROUND CONSISTS OF 2 SKIPS COKE & 1 SKIP ORE & STONE & 1 SKIP ORE & STONE.
2- SMALL BELL MUST BE CLOSED 7 SECONDS BEFORE CONCLUSION OF TRIP OF SKIP (DEFINING LINE SHOWN DOTTED)
STANDARD BLAST FURNACE
DIAGRAM OF CHARGING
VARIANT I

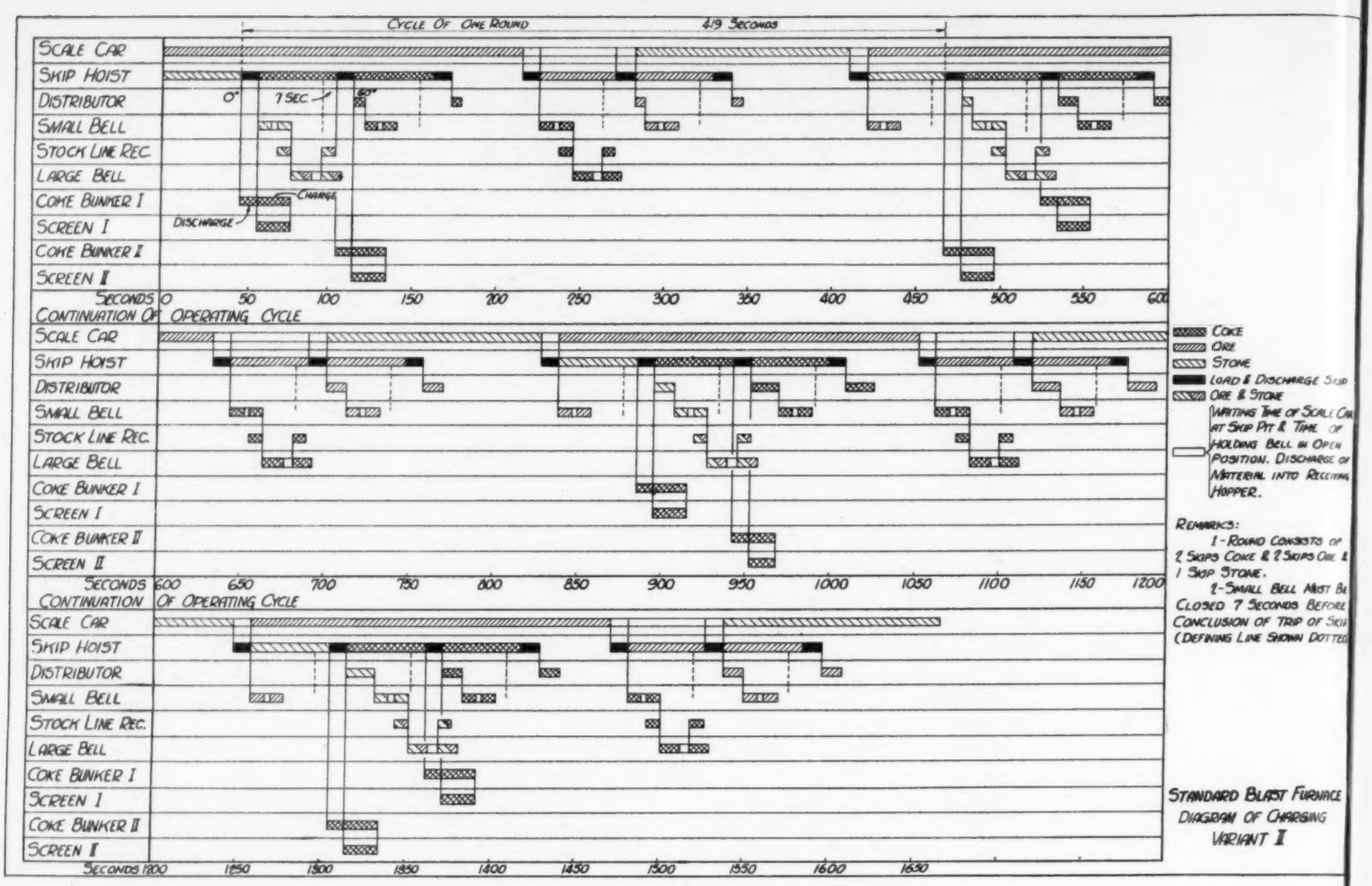
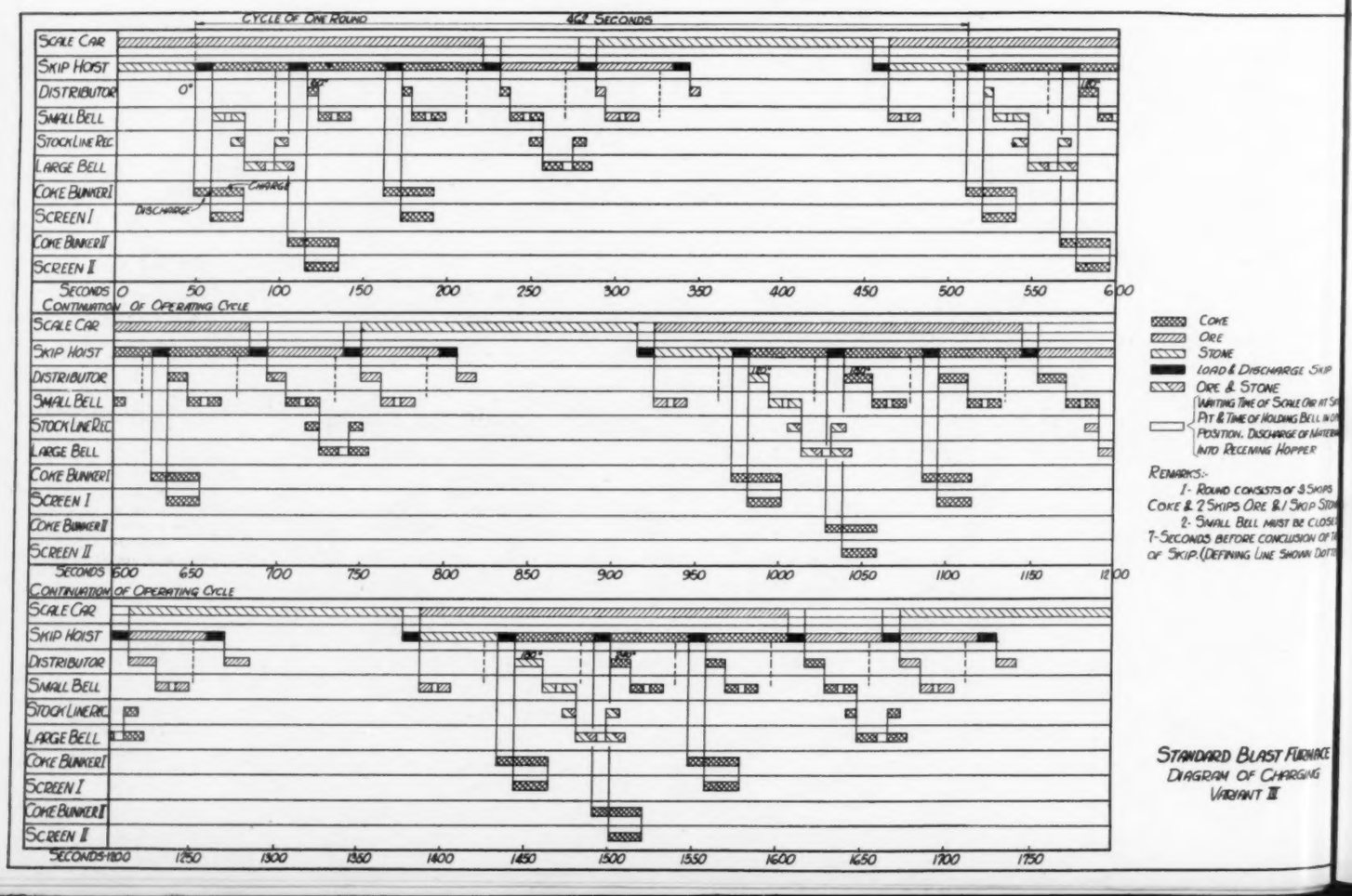

Cycle Of One Round
419 Seconds
Scale Car
Skip Hoist
Distributor
Small Bell
Stock Line Rec.
Large Bell
Coke Bunker I
Screen I
Coke Bunker II
Screen II
0°
7 Sec.
60°
Charge
Discharge
Seconds 0 50 100 150 200 250 300 350 400 450 500 550 600
Continuation Of Operating Cycle
Seconds 600 650 700 750 800 850 900 950 1000 1050 1100 1150 1200
Continuation Of Operating Cycle
Seconds 1200 1250 1300 1350 1400 1450 1500 1550 1600 1650
Coke
Ore
Stone
Load & Discharge Skip
Ore & Stone
Waiting Time of Scale Car at Skip Pit & Time of Holding Bell in Open Position. Discharge of Material into Receiving Hopper.
Remarks:
1-Round Consists of 2 Skips Coke & 2 Skips Ore & 1 Skip Stone.
2-Small Bell Must Be Closed 7 Seconds Before Conclusion of Trip of Skip (Defining Line Shown Dotted
Standard Blast Furnace
Diagram of Charging
Variant II

Figure 6—Time study of all charging operations.

Figure 7—Time study of all charging operations.


Cycle Of One Round
462 Seconds
Scale Car
Skip Hoist
Distributor
Small Bell
Stock Line Rec.
Large Bell
Coke Bunker I
Screen I
Coke Bunker II
Screen II
0°
60°
Charge
Discharge
Seconds 0 50 100 150 200 250 300 350 400 450 500 550 600
Continuation Of Operating Cycle
Seconds 600 650 700 750 800 850 900 950 1000 1050 1100 1150 1200
Continuation Of Operating Cycle
Seconds 1200 1250 1300 1350 1400 1450 1500 1550 1600 1650 1700 1750
Coke
Ore
Stone
Load & Discharge Skip
Ore & Stone
Waiting Time of Scale Car at Skip Pit & Time of Holding Bell in Open Position. Discharge of Material into Receiving Hopper
Remarks:-
1- Round consists of 3 Skips Coke & 2 Skips Ore & 1 Skip Stone
2- Small Bell must be closed 7-Seconds before conclusion of Trip of Skip. (Defining Line Shown Dotted
Standard Blast Furnace
Diagram of Charging
Variant III

hydraulic cylinders on the furnace top. The two-drum, single-motor electric hoist for operating both bells is well adapted to this type of bell arrangement. This type of layout was avoided in the Gipromez design principally for the following reasons:

(a) It was considered desirable to avoid heavy counterweights and other mechanisms on the furnace top.

(b) Fully counterweighted bell arrangement may lead to destructive accidents resulting from explosions between bells.

(c) Greater mechanical effort required—higher cost of equipment—absence of several of the advantages inherent in the pneumatic hoist.

2. Those in which the bell lever is only partially counterweighted and the bell is held closed by a downward pull at the end of the lever. This type of mechanism was selected for the Gipromez standard furnace, in combination with pneumatic cylinders, for the following principal reasons:

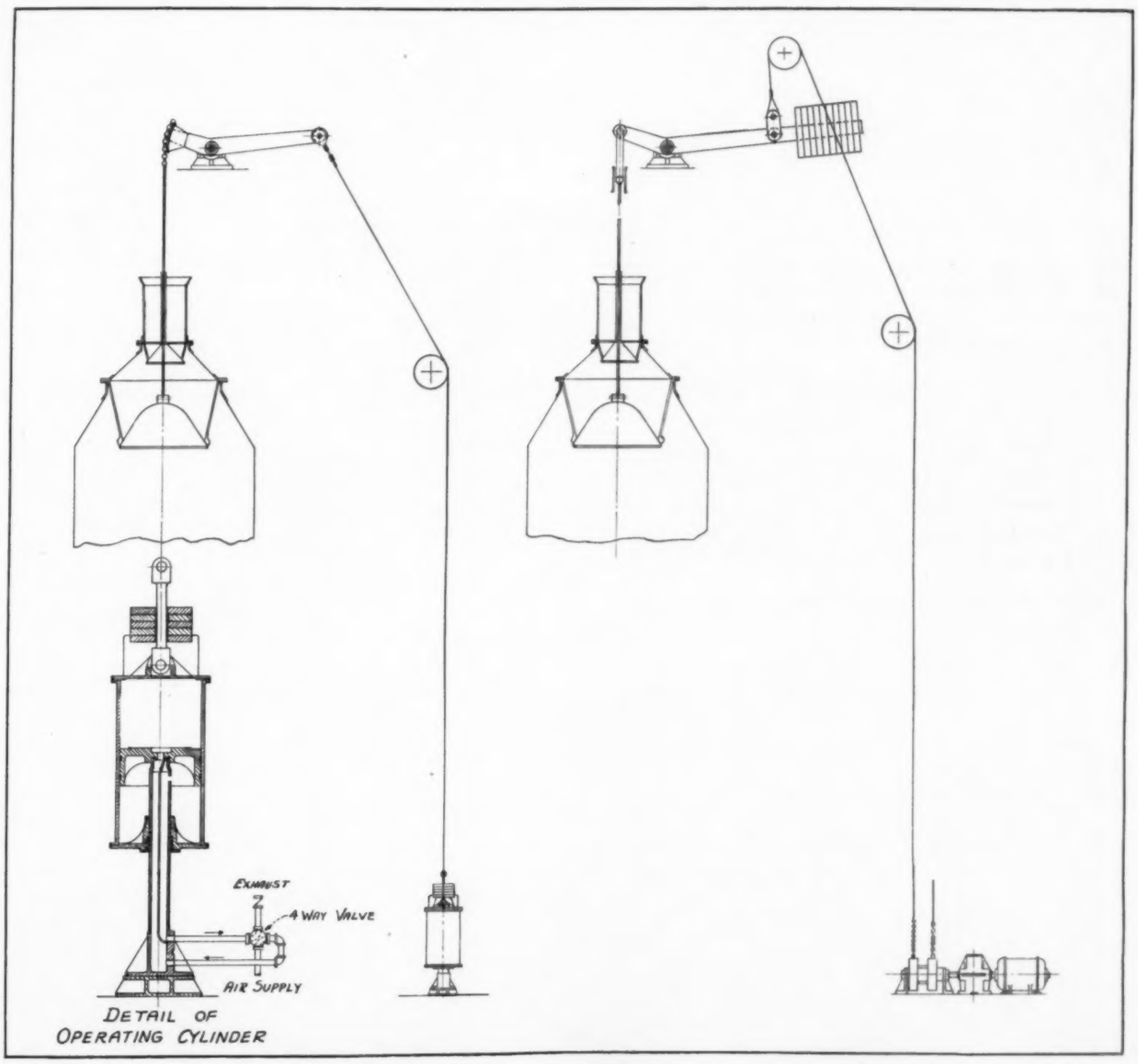
(a) Inherently a device with short linear movement, the bell cylinders function directly with no intermediate mechanism, are most simple, have few moving and wearing parts, only slow-moving parts, and little inertia.

(b) Cables can be directly and simply run. Since the forces and movements are vertical, there are no side-thrusts and the cylinders are easily anchored in position.

(c) Involve minimum counterweight and inertia. Since the bell is held closed by pneumatic pressure, an explosion between bells is relieved by an elastic medium with minimum shock. No slam is possible comparable to that when a counterweight is raised or held up and suddenly dropped. This slam has caused more wrecks than one. Pneumatic operation is almost complete insurance against impact stresses and consequent failures.

(d) Closure is elastically cushioned, is not

Figure 8—Bell hoist diagram.



dependent upon limit-switch settings, is least affected by cable stretch.

(e) Can be located in the skip engine house. Requires minimum floor space, conveniently situated substantially reduces size of skip engine house.

(f) Time of opening-pause-closing are independently adjustable, within limits.

(g) In case of failure of electric power, bells can be operated through manual manipulation of their control valves. Minimizes danger of overheating and warping the large bell.

(h) An empty (or loaded) large bell can be opened, with any top pressure, by equalizing the pressure above this bell through an electrically operated valve. (Not shown in charging diagram, acts in unison with raising and lowering of stockline rods and does not increase time requirement.)

(i) Much lower in first cost. Simple equipment readily produced in Soviet Union.

(j) Pneumatic cylinders with electrically operated valves use simple control which can be readily built into a full automatic charging control system.

It is my own opinion, as an electrical engineer, that the pneumatic cylinder is a "natural" and is ideally suited for bell operation of the type under consideration. The best that an electric hoist can possibly do is to approach the ideal which the pneumatic method affords. This is one of those occasional operations which cannot be done better electrically, in fact, it cannot be done as well. The myriad types of electric bell hoists which, through the years, have been tried and superseded by still other designs, bear mute testimony to this fact.

DISCUSSION

PRESENTED BY

S. L. HENDERSON, Electrical Superintendent, Furnaces and Docks, Carnegie-Illinois Steel Corporation, Cleveland, Ohio.

G. FOX, Vice President, Freyn Engineering Co., Chicago, Ill.

L. DEESZ, Combustion Engineer, Republic Steel Corporation, Youngstown, Ohio.

L. E. RIDDLE, Superintendent Blast Furnaces Carnegie Illinois Steel Corporation, Duquesne, Pa.

S. L. HENDERSON: I should like to ask Mr. Fox, where it is desired to carry a stack level at six feet, what has been done to prevent over-filling?

G. FOX: Indicating lamps, associated with the stockline recorder, are located in the stock house. These show the scale-car operator, who is the master of events, just where the burden level is at all times. To emphasize these numerical indications, lamps of one color indicate when the burden is low, lamps of another color indicate the normal range of burden levels, and lamps of still another color burn when the stockline nears its uppermost limit. This arrangement seems to be entirely adequate. We have not found it necessary to interlock with the stockline recorder to prevent filling the furnace when the burden is way up, although such an interlock could probably be provided if the need were evident.

S. L. HENDERSON: I would like to ask another question. Where a steam and skip hoist is used, what method do they use for stopping the skip automatically when the bell operations have not been completed? Do they close the throttle on the incoming steam or close a valve in the exhaust line?

G. FOX: All of the charging control installations thus far made have been associated with electrically driven skip hoists. Steam-operated bell cylinders have been successfully controlled, using motor-operated steam valves. Similar arrangement could no doubt be applied to a steam-driven skip-hoist but we cannot speak with the authority of experience on this point. We haven't crossed that bridge because, as yet, we haven't come to it.

L. DEESZ: I think it would be a good idea if Mr. Fox would tell us what to do when the ore freezes up, around 60 degrees below zero. When that is the average temperature over three months, how do you get it into this charging equipment and scale cars?

G. FOX: When Mr. Deesz says cold weather, he means cold weather, he has experienced Siberian winters where 40 degrees below is commonplace.

Most of the troubles resulting from extreme cold arise in connection with incoming cars, with ore in storage piles or in the bins. After materials reach the scale car, they keep moving and don't have much chance to freeze up. The ore bins associated with the standard blast furnaces are of fabricated steel. Probably the most prevalent means of heating is by salamanders located in the stock house.

Since ore-freezing troubles are most likely to cause scale-car delays, the most effective means to combat them lies through minimizing and simplifying scale-car movements. This can be done, for instance, through such a round as two skips of coke, one of ore, two of coke, one of ore and one of stone. In such a round seven skips handle as much material as ten skips required for two rounds such as shown in Variant 2. The ore-handling and ore-weighing movements particularly are minimized.

The amount of time which can be saved by speeding up the movements of furnace charging mechanisms is not at all comparable with the economy of time possible through short-cuts in charging schedules. It is neither effective nor rational to attempt to compensate for scale-car delays by operating the other charging mechanisms at disproportionately high speeds.

It should be noted that with the charging schedules diagrammed, the furnace can be kept filled in about 50 to 75 per cent of the total time so that, even with these schedules, there is considerable leeway to permit the filling to catch up after the burden has settled.

L. DEESZ: Where does the air come from in the cylinders?

G. FOX: The pneumatic cylinders use air at a pressure of about twelve or fifteen pounds per sq. in. In a large furnace the cold blast line almost continuously carries a pressure somewhat greater than this. So the cold blast is a convenient and cheap source of this air. Cold air which has been taken into a turbo blower and which has been heated, incidental to compression to low pressure, is not a likely source of much moisture. In the modern skip-engine house which is tightly constructed, the losses from the hoist motor and its resistors ordinarily temper the room enough to eliminate any liklihood of freezing troubles. However, it is a simple matter to provide supplementary heating if it should be deemed desirable.

To supplement the cold blast source of air, it is usual practice to provide a connection with the 100 pound plant supply. This passes through a reducing valve which functions automatically to maintain pressure in the event that the cold blast line pressure falls, as at casting time, for instance.

Perhaps the best answer to this question is to be found in the fact that a number of American installations of this type, properly made, have had no appreciable trouble from freezing. Some of the Russian blast furnaces so equipped have made record tonnages, equalling or exceeding rated furnace capacity, in the dead of winter.

L. E. RIDDLE: This paper covers the handling of materials so well that we have but little criticism on account of the mechanical perfection of the whole scheme of charging. We do think, however, that it is wrong to design the large bell hopper so small that the volume capacity for holding stock on it is limited to about 750 cubic feet. We have found it necessary to charge as much as 85,000 pounds at one lowering of the large bell, and have experimented with amounts up to 107,000 lbs. Regardless of the type of materials used we believe with the modern large furnaces with large stock lines there should be a capacity of at least 1400 cubic feet in this hopper. We think it wrong to design a top that limits an operator to a small charge.

Some furnace irregularities due to poor distribution cannot be corrected on account of the inability to drop into the furnace a charge of size sufficient to correct the trouble. We believe that furnaces with given material, due to their physical make-up, need certain size charges dropped into the furnace to give best results. This becomes more apparent and necessary as we go to large stock line areas. With small large bell hoppers and large stock line diameters, we may be handicapped when we have to use materials of certain physical nature, due to our inability to charge into the furnace at one lowering of the large bell, charges which would give beneficial results.

We believe that continuous stock line recording devices such as were installed on this furnace are absolutely essential to best practice.

It is still questionable if the automatic coke weighing gives as much regularity as charging by volume. We like the central coke bins. We believe the cycle filling as presented is the best for speed and accuracy in weights. We have carefully checked over the time allowed for each movement of cars, skip and bell and find this adequate. We agree that speed when unnecessary is a distinct liability.

While many mechanisms, air, oil and electrical, counterweighted levers and those not counterweighted have been used with satisfactory results, we believe the pneumatic cylinder is best, requires the least attention and is less susceptible to failure than electric hoists.

Mr. Fox has presented more data on the time factors in charging than we have previously seen, and he is to be commended on its excellence.

G. FOX: There is variance in the preferences of individual operators as to the most desirable size of large-bell hopper. These differences in opinion may result, in part, from differences in character of materials charged. As pointed out by Mr. Riddle, a very large hopper permits the expedient of handling a very large single charge. On the other hand, increase in hopper dimensions generally involves increase in distance for coke to drop, this feature being objectionable to some.

A pneumatic cylinder bell hoist is being currently applied to a new American 1000-ton furnace, having a capacity for 90,000 lb. burden on the large bell.

Increase in large-bell hopper capacity would seem to have no influence upon the general principles of charging under discussion, except perhaps to further emphasize the desirability of moderate operating speed.

Preference between coke weighing and charging by volume seems to depend largely upon the two variables, coke size and moisture. Where size is uniform but moisture content is widely variable, volume charging gives a more definite result. Conversely, where coke sizes tend to vary considerably, weighing may be the more accurate method. In Russia, the latter condition prevailed.

Modern Refractories

FOR THE STEEL INDUSTRY

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Presented before the Annual Spring Conference of the A. I. & S. E., Youngstown, O., April 22-23, 1936

▲IN THE period which ended approximately with the years just preceding the depression, the steel making and refractories industries ran parallel courses in one respect. Both were interested primarily in producing as economically as possible large tonnages of durable goods. In the interval, a culmination of forces, with the recent economic crisis possibly the motivating factor, have caused in both industries a distinct change in attitude toward products and processes. The call for lowering of steel production costs and for special steels by special processes has had its counterpart in a demand for improved refractories of all types.

The refractories producers have been equal to this demand. From the accumulation of data which has been building up on the fundamental properties of materials and by intensive studies of processing methods, the producers have developed and learned to control to a very advanced degree, many of the latent properties of their materials.

This is to be contrasted with the idea, formerly maintained, that the properties of refractories were rather fixed and that furnace operations must be adapted to the limiting weaknesses of the brick. The improvement made in the spalling resistance of magnesite and chrome brick, is but one example of adapting the refractory to the furnace instead of vice versa.

An objective that both the refractories producers and consumers can now afford to pursue is an intensive study of the varying conditions which shorten the life of refractories in metallurgical furnaces. Such studies would serve as a basis for making a break-down of these complex factors so that the refractories manufacturers could apply their ability to produce brick of specific function.

RAW MATERIAL SUPPLIES

The improvements and changes in the properties of the finished refractories now delivered to the steel plant are not, generally speaking, the result of novelties in raw material supplies. The fireclays from Pennsylvania, Kentucky, Ohio, and Missouri remain the chief sources of supply of material for fireclay brick. Continual prospecting is necessary as older mines become depleted, but a supply of good flint clay appears in sight for all future needs. The diaspore clays from Missouri and kaolin from Georgia continue as the chief sources of supply for the high alumina and special refractories made from these materials. Ganister for silica brick is still quarried chiefly from the ledges and floes of Pennsylvania and Wisconsin. Except for small tonnages of dead burned magnesite from Russia and California and the attempts to use domestic olivine, the south European and Washington magnesites remain the sources of supply of basic material. Chrome ores from Cuba, Africa, and Greece are essentially of the same type that have been imported for years. The chief novelty in refractory material of consequence, is the cyanite ore from India used for making the so-called sillimanite refractories.

The improved refractories of today accordingly are not the result of new raw materials but rather the result of a better understanding of their properties and the reduction to practice of methods of developing and controlling them.

PHYSICO-CHEMICAL CONSIDERATION OF SOME PROPERTIES OF REFRACTORIES

The entry of the physical chemist and technical engineer into the refractories field did not occur as early as the entry of the metallurgist in the metal-melting industry, but product improvement in both industries has proceeded at an accelerated pace coincident with the infiltration of these men with the same type of mental approach to their problems.

Physico-chemical concepts of refractories teach that many of the properties of these materials, due to the process of manufacture as well as subsequent action in customers furnaces, can be anticipated from the use of the phase-rule diagram with which the metallurgist also works.

The equilibrium diagram of the system Al_2O_3-SiO_2 as worked out by Bowen and Greig (1) for example, serves as a guide map for experimentation over the entire range of aluminum silicate refractories. These include fireclay, kaolin, diaspore, mullite, and high alumina brick. The melting point and crystal to liquid relationships indicated, are of course, worked out for the pure oxides SiO_2 and Al_2O_3. These relationships

in turn are affected by the presence of small amounts of other minerals such as iron oxide, lime, magnesia, and alkalies, often associated with the natural aluminum silicates as mined, or deposited on and absorbed during usage.

Our great deposits of fireclays, from which brick with their multitudinous purposes must continue to be made for economic reasons for many years to come, present a never ending problem of control, particularly during firing. The question of making suitable brick from these clays, in the light of the equilibrium diagram referred to, is the problem of converting an almost amorphous raw material into a stable mass of maximum crystallinity. The limiting factor in what can be done during the firing of the clay, and subse-

L. J. TROSTEL

quent exposure in a furnace, is largely the action of the liquid which forms with the crystalline material. This liquid as it forms serves the useful function of drawing the clay particles together by surface tension into a dense mass and acts as a matrix to bond it. This causes the shrinkage associated with fireclay brick. Sometimes certain impurities are present which decompose as the heating is continued, causing evolution of gases and swelling of the liquid. This causes one type of expansion of fireclay brick. With an understanding of these phenomena we have taught ourselves that if we painstakingly submit our raw clays to a series of time-temperature tests, we can anticipate rather exactly the volume stability of the brick we can make from the clays as well as the subsequent stability of the brick in service. Such tests, however, must be for periods long enough, and over a temperature range extensive enough, to anticipate the future life of the brick.

It has been well known for years that refractories of nearly 100 per cent crystalline material, have certain very desirable properties. Silica brick for example, are highly crystalline, possess high load carrying ability and serve as excellent roof brick. Reference to the equilibrium diagram of the system Al_2O_3-SiO_2 will indicate that the best fireclay brick, containing about 42½% alumina, when maintained at a temperature of 1600°C., (2912°F.) which is not at all unusual in some furnaces, is nearly 45 per cent liquid and only 55 per cent crystalline mullite. It is easy, to appreciate why such a mass is not always able to carry the high static loads which are encountered in furnace roofs. The logical trend in the search for better aluminum silicate refractories has been for a mineral which can be readily converted to nearly 100 per cent crystalline mullite. The natural highly crystallized members of the sillimanite group of minerals upon heating make the closest approach to this ideal situation. Cyanite is a natural mineral of this group which has found an increasing use as a refractory material.

Two thin sections, both photographed at 85 magnifications, are shown in Fig. 1 illustrating varying degrees of crystallinity in aluminum silicate refractories. On the left is a well burned high heat duty fireclay brick of about 40 per cent alumina. Approximately 55 per cent of crystalline mullite is present, but the crystals are very small and associated with so much liquid that they cannot be seen. Contrast this section with the one at the right of Indian cyanite. This converts on calcining to about 90% mullite of practically the same type of intermeshed needles.

The production of refractories from cyanite has presented few difficult manufacturing problems since the data on the fundamental properties of the mineral mullite were worked out thoroughly almost at the same time that satisfactory deposits of cyanite were located. In other words, the course was well charted before attempts were made to manufacture the product.

The manufacture of good silica brick possibly has been easier from the start than any of the common refractories, in spite of the fact that silica has seven different crystalline modifications of varying temperature stability. In the first place an unlimited supply of nearly 95% pure crystalline raw material has been available and secondly the stability relations of the various crystalline modifications as worked out by Fenner (2) were available to refractories manufacturers very early. This early scientific knowledge was so complete and exact that it has kept us from making many mistakes and accounts for the fact that few changes have been made in the manufacturing operations or properties of silica refractories.

The prior development of knowledge of properties dependent mostly on composition has been followed more recently by close scrutiny of the mechanics of certain physical properties, which result largely from processing and are factors in the subsequent life of refractories.

(1) M. L. Bowen and J. W. Greig. "The System Al_2O_3-SiO_2", Journal American Ceramic Society 7 (4), 238-254 (1924).

(2) Fenner, C. N. The Stability Relations of the Silica Minerals Amer. Jour. Sci. (1913) 36, 331-384.

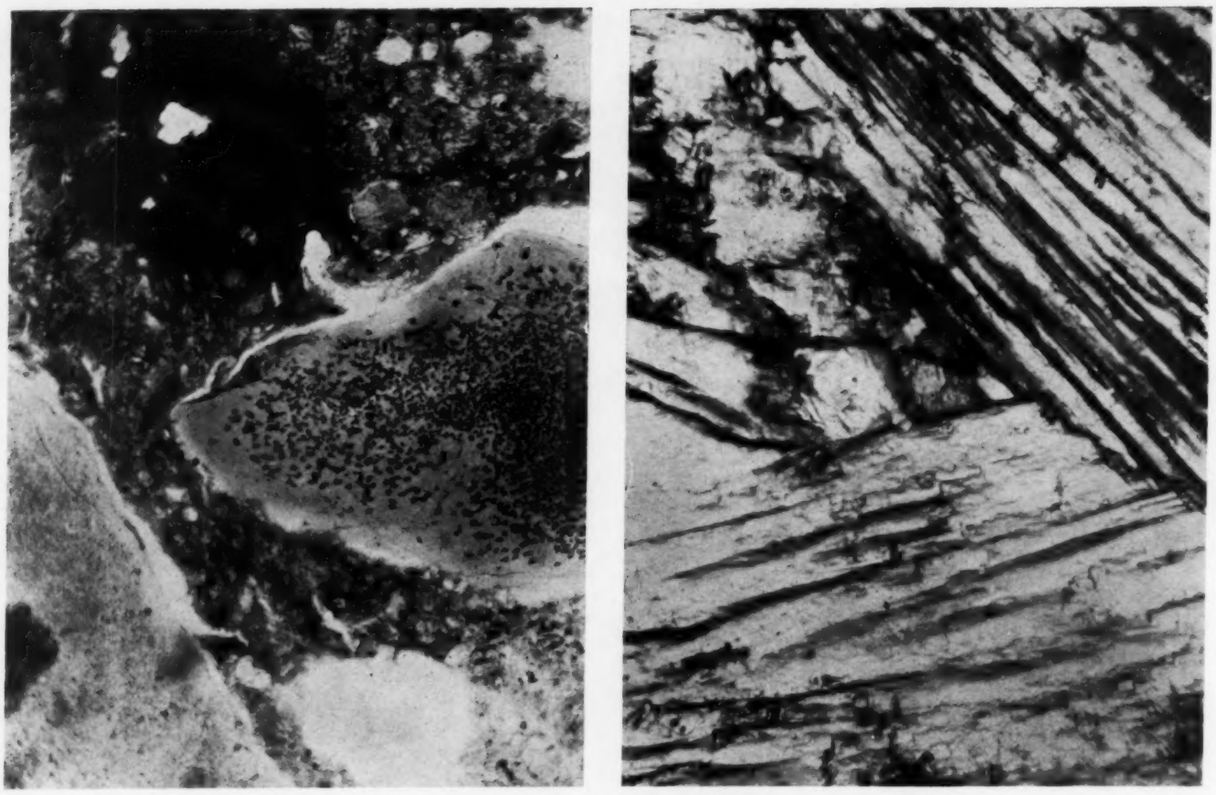


Fig. 1—Comparative crystallinity of hard burned fireclay brick and Indian cyanite.

If we except erosion and slagging, the most common type of failure of refractories is spalling. Fortunately a much better understanding has been gained of the forces causing this type of failure and the manner in which these forces may be controlled within limits. For many years we proceeded on a theory unsupported by careful physical studies that all spalling was due to pure thermal shock resulting from rapid and wide temperature fluctuations. Later, it was realized that spalling was a much more complex phenomenon and was related to not only thermal shock but structural, or textural changes in the brick. These changes are due to the particular refractoriness of the material as well as method of manufacture and are evidenced by varying degrees of vitrification, as well as by shrinkage in service.

Recent studies by a number of investigators in this country have emphasized the importance of certain definite measurable properties of refractories related to spalling. One property termed extensibility or maximum strain, is the elongation per inch of length at failure, and serves as an index of the ability to stretch without rupture. The second is thermal expansion. Numerically, extensibility is computed by dividing the modulus of rupture by the modulus of elasticity. As indicated by the directional arrows in Fig. 2 (1) the spalling resistance of fireclay brick may be increased by increasing the extensibility or decreasing the thermal expansion. These two properties in turn are affected

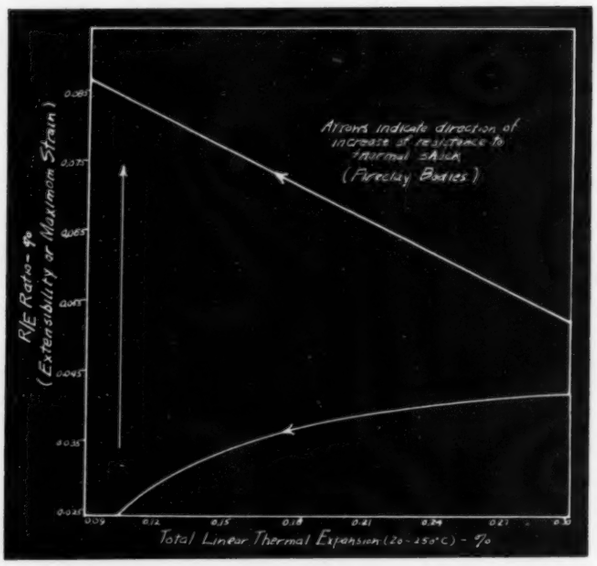


Fig. 2—The arrows in the above illustration indicate the direction of the increase of resistance to thermal shock.

(1) Adapted from data in Research Paper 827 by R. A. Heindl, National Bureau of Standards (1935). The area enclosed by the boundry curves includes a number of fireclay mixes of varying composition and burn.

by practically all the various unit operations involved in manufacturing a refractory. The extent to which grain size, mix, molding pressure, and burn affect spalling in the light of the above theory, has engaged the attention of the refractories manufacturers. This has necessitated much careful plant experimentation pointing the way to the production of more spalling resistant brick.

MODERNIZATION OF THE UNIT OPERATIONS FOR PROCESSING REFRACTORIES

To keep in step with the increased demands for improvement in the properties of refractory products resort has not been made to the use of new types of raw materials, as was pointed out, but to better methods of manufacture.

In general, the conventional manufacture of refractories has always been effected in five unit operations:

(a) Grinding and Screening
(b) Mixing
(c) Pressing or Molding
(d) Drying
(e) Burning

The recognition of high bulk density, in any given group of refractory materials, as the most important single property which may be controlled in manufacture, and which affects the greatest number of other important properties in service, such as strength, volume stability, slag and spalling resistance, and heat capacity, has resulted in the application of most of the more novel principles in manufacturing.

Grinding

The first point of approach to increased density obviously is the size of the grains constituting the batch. A number of refractories are now available in which high density is achieved by carefully screening out grains falling within certain size bands, and recombining them in definite proportions. It has been found by experimentation that the densest mixtures closely approach binary systems of rather coarse and fine grains, in which the proportion of coarse to fine particles is about 55:45 per cent, and the percentage of intermediate particles is maintained at a minimum. The application of this principle is, of course, modified by a number of factors. It may be used most successfully on hard and highly crystalline materials which do not compact readily under pressure and conversely is of least value in brick mixes of inherently high plasticity.

Mixing

The true function of the mixing operation is now recognized to be the distribution of the plastic or bonding materials so as to coat thoroughly the non-plastic constituents. Thus, there is provided a lubricant during the subsequent molding operation to create free plastic flow of the batch particles and permit them to be bonded to a mass with a minimum amount of voids. Improvements in mixing have been made where the percentage of plastic material is low as in the dry press method by the use of pans or other special mixing equipment constructed to more effectively rub or coat the plastic material on the non-plastic grains. In order to prevent crushing of the established grain sizes during mixing in wet pans, numerous schemes are being tried to take some of the pressure of the muller wheels off the batch. Light mullers, raised mullers and even no mullers, are in use.

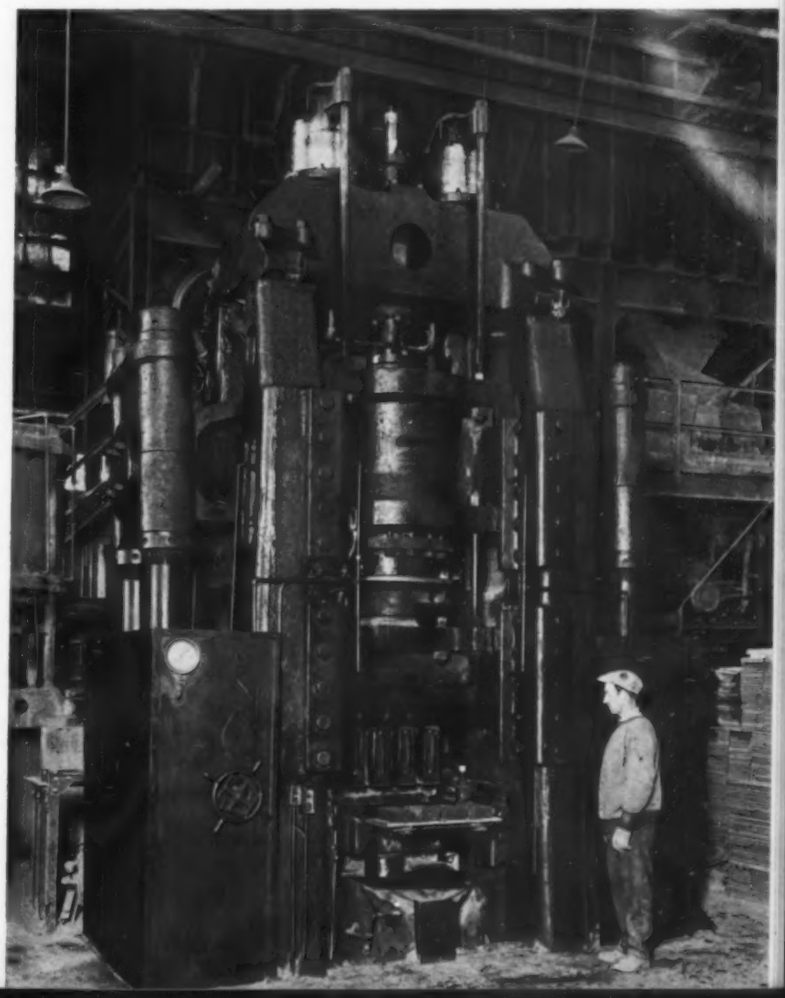
Molding

An obvious method of increasing density, attended by many practical difficulties, has been to increase the molding pressure, particularly of dry-pressed refractories. This did not follow until one manufacturer had the courage to install a specially constructed high-speed hydraulic press shown in Fig. 3 for regular brick production, capable of pressing at 10,000 lbs./sq. in. This press stepped up the pressure 5 to 10 times over that attained on the usual mechanical press.

Compression of the air entrapped in the voids of dry press brick during high speed pressing, with subsequent expansion upon sudden release of the pressure, results in a very undesirable type of lamination or pressure crack, and the higher the pressure, the worse the lamination. In order to take advantage of the high density possible with extremely high pressure, de-airing of the brick during pressing has been necessary.

The de-airing of dry press brick is now accomplished by the use of a vacuum, either through vents in the

Fig. 3—A specially constructed high-speed hydraulic press capable of pressing 10,000 pounds per square inch.



sides of the mold box, or through perforated or porous plates at the top and bottom of the mold box.

Successful de-airing of stiff mud brick by vacuum has extended rapidly since 1932 in the industry and the number of installations exceed those for the de-airing of dry-press brick. In the stiff mud de-airing process the moistened and shredded clay is fed from a pug mill into a chamber maintained under a vacuum of about 25″ of mercury and then extruded as a continuous column by an auger through the die which forms the ware. A cross section of the well-known Chambers machine is shown in Fig. 4. Improved density and nearly complete elimination of the lamination planes sometimes typical of products made by this molding process, are accompanied by a very high increase in strength.

The molding of large special shapes, which do not adapt themselves to machine molding, has been improved by borrowing some of the advantages of the other processes, particularly by tamping with pneumatic tools. This method produces shapes of very high density and uniform workmanship equivalent in every way to brick made on the most powerful presses.

Drying

Drying is necessary to remove excess moisture. Many mixes contain as much as 15% moisture. The removal of this much moisture results in considerable shrinkage. If the drying process is not carefully controlled, drying shrinkage can be accompanied by distortion, warping and cracking. Drying equipment has been improved to provide uniform rate of moisture removal from all surfaces, strains have been eliminated and workmanship has been generally improved.

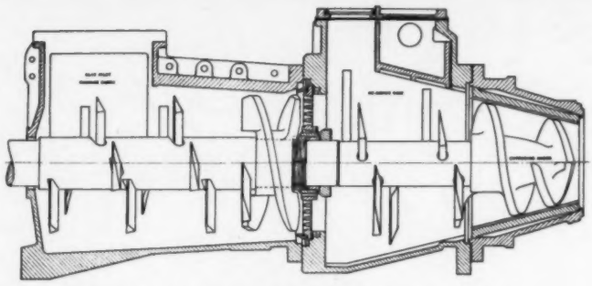
Burning

Burning, or firing, has two important functions. One is to develop a permanent bond in the shaped ware, by partial vitrification of the mix, and the other is to develop temperature-stable mineral forms of the major component of the mix.

The firing treatment involves volume shrinkages as high as 30 percent for clay ware and 20-40 percent for high alumina products made from diaspore clay. Volume expansions of nearly 15 percent result in the burning of silica brick. Severe strains are thus often set up, evidenced by cracking, warping and kiln marking of brick.

Rather than delay the entire development of the temperature stable form of the minerals in most refractory materials, until the final firing stage, it is now recognized that it is frequently better to start off with material as nearly pre-stabilized as possible and reserve as the chief function of the firing treatment, the maturing of the bond. There are thus eliminated the strains accompanying the various mineral changes involved, and the original advantage of tight interfitting of sized grains, to set up high density, is maintained.

This trend to pre-stabilization of the grog by the development of high crystallinity, is well advanced. In the aluminum silicate group, including fireclays, kaolins, some diaspore clays and the sillimanite minerals, mullitization or the development of the mineral



Illustrating the inside of a Chambers' de-airing machine.

Fig. 4

mullite, $3Al_2O_3.SiO_2$, is the goal. Calcined clays have always been part of the batch in making many fireclay refractories, but the temperature of calcining has frequently been lower than the temperature of firing the brick. Many of the kaolin and diaspore refractories intended for high heat and super duty service now contain clays whose pre-calcining temperature has been stepped up. A well-known brand of kaolin refractory, in which mullitization is well advanced, consists largely of kaolin pre-calcined above 1650°C. (3002°F.).

The so-called dead-burned magnesite used in making magnesite refractories has always been calcined in rotary kilns to temperatures of about 1550°C. (2822°F.) of necessity to get rid of the CO_2 constituting about 50 per cent by weight of the original mineral and to crystallize the MgO to periclase, iron oxide often being used as a mineralizer.

The attainment of very high crystallinity has reached its ultimate commercial development in two superheating processes, of quite different character. The one being used in this country depends upon crystallization from a completely liquid phase. The other in Germany is conducted almost entirely as a solid phase reaction. Both processes promote such a high degree of grain growth that practically zero porosity results in the finished product.

The German method has been applied successfully to the manufacture of small special refractories using a material such as pure Al_2O_3 and employs a temperature of about 1800°C. (3272°F.). This is nearly 300°C. (540°F.) higher than that usually maintained in the hottest kilns, such as those burning silica brick.

The other method, as used in America, by the Corhart Company, is a radical departure from the established unit operations of the industry. The flow sheet of the process of this company could very easily be that of a steel foundry. The clays and ores used are mixed in the proper proportions to yield a mixture of the minerals (mullite and corundum), melted in an electric furnace of the Heroult type and poured into molds of the desired shape. An operating temperature of 1900°C. (3452°F.) is required to liquify the charge. The method is also in use in Europe for producing refractories of a chrome-magnesite type.

Further, in this country, prestabilized materials are being processed in a manner which eliminates the burning step in the manufacture of magnesite and chrome refractories.

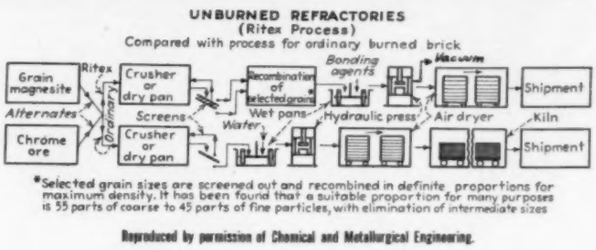


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Fig. 5

IMPROVED REFRACTORIES AVAILABLE FOR STEEL-MAKING

The outstanding products which have been developed to meet some of the steel makers requirements for refractories better able to withstand operating conditions of increasing severity, and in lowering steel costs, and adaptable to furnaces of changing design are: Improved basic brick of high resistance to spalling and low thermal conductivity; crystalline base refractories from cyanite of high density and spalling resistance; super-duty fireclay brick exhibiting negligible volume change at high temperatures and of unusual resistance to spalling; general improvement in ordinary first quality fireclay brick; and insulating brick of high refractoriness.

Basic Brick

Probably the most outstanding changes in refractories supplied to the steel industry in recent years have been in the character of the basic group.

Some of the better known improved products of this group have been the Ritex series of chrome (1) and magnesite (2) brick, burned chrome brick containing magnesite, and magnesium silicate brick consisting essentially of the mineral forsterite.

The technologists of both producing and consuming groups have long been aware of the anomaly of carrying on melting operations with basic slags and oxides in contact with acid refractories. Therefore, it is not surprising that so much development work has been carried on to produce basic brick sufficiently improved in their former outstanding weakness, spalling resistance, that they could be substituted for the acid brick.

The flow sheet of the Ritex process for both magnesite and chrome brick is compared with that of the regular burned process in Fig. 5.

The brick are made by adding inorganic refractory bonding materials to the mix so that it develops high strength after 24 hours drying. Forming pressures have been stepped up 10 times to nearly 10,000 lbs./sq. in. using the high speed hydraulic press shown in Fig. 3. Interfitting of grains has been developed to a maximum by using only selected particle sizes and combining these in proper proportions. This careful grain-sizing greatly intensifies the effect of the high molding pressure in reducing the voids between grains. The brick have high strength, high density, improved resistance to spalling and are lower in thermal conductivity and gas permeability than regular burned brick.

The improved resistance to spalling of the Ritex chrome brick is brought out in Fig. 6 and 7, illustrating the condition of the brick after a simulative service spalling test.

This test is a modification of the A.S.T.M. panel test (3) designed to show under accelerated conditions the resistance to combined thermal and structural spalling. The brick were laid up as stretchers in a panel, backed up with 4½" of insulation, heated to 1650°C. (3002°F.) and held for 24 hours, and then allowed to cool slowly to room temperature. After this treatment the panels were subjected to a spalling treatment consisting of first heating to 1200°C. (2192°F.) for 10 minutes and then cooling a similar length of time with a blast of air delivered at the rate of 1400 cu. ft./min.

On the left in Fig. 6 are shown regular burned chrome brick which vitrified, cracked and eventually lost about 31 per cent of their weight after a total of 10 complete cycles of heating and cooling. On the right are shown the Ritex-Chrome which came through the same test with no cracking, shrinkage, or loss in weight.

On the left in Fig. 7 are shown some burned chrome improved by the addition of magnesite. These, after 20 cycles of heating and cooling, lost 12 per cent in weight. On the right are shown the Ritex-Chrome brick which show no loss after the same treatment.

Thermal conductivity test data comparing both regular burned chrome brick and Ritex-Chrome are shown in Fig. 8. For comparison, similar measurements on commercial silica brick of average grade are included. These measurements were made using the type of apparatus described by Wilkes (1). It will be noted that the Ritex-Chrome brick not only show the lowest conductivity but a negative temperature coefficient. This means that with increasing temperature, the conductivity continues to become even less. The Ritex-Chrome brick, further, have a lower conductivity than commercial silica brick at temperatures exceeding approximately 500°C. (932°F.). Previous measurements with Ritex-Magnesite brick also show that their conductivity is less than that of burned magnesite brick.

These comparative data are, of course, of most interest where consideration is being given to the substitution of basic brick for silica, such as in open-hearth furnaces above the slag line, where the necessity for conservation of heat is considered desirable.

The high density characteristic of these brick, is indicated by both low open pore content and low gas permeability. The open pores of the Ritex-Chrome, for instance, are as low as 8.5 per cent. This is to be compared with 23.2 per cent for burned chrome brick. In permeability tests made with the Pressler (2) apparatus, in which the pressure was varied from ½ to 8 inches of water, the permeability value expressed as a factor K for Ritex-Chrome brick averaged 0.0018 and

(1) R. P. Heuer "A New Application of the RITEX Process to the Manufacture of Chrome Brick". Steel, 1935, Vol. 97, No. 8.

(2) A. E. Fitzgerald "New Developments in Unburned Magnesite Brick for the Metallurgical Industry". Mining and Metallurgy, 1931, Vol. 12, No. 300.

(3) Panel Test for Resistance of Refractory Brick to Thermal and Structural Spalling C38-36. A. S. T. M. Proceedings Vol. 36, Part I.

Fig. 6—On the left are shown regular burned chrome brick which vitrified, cracked and eventually lost about 31 per cent of their weight after a total of 10 complete cycles of heating and cooling. On the right are shown the Ritex-Chrome which came through the same test with no cracking, shrinkage, or loss in weight.

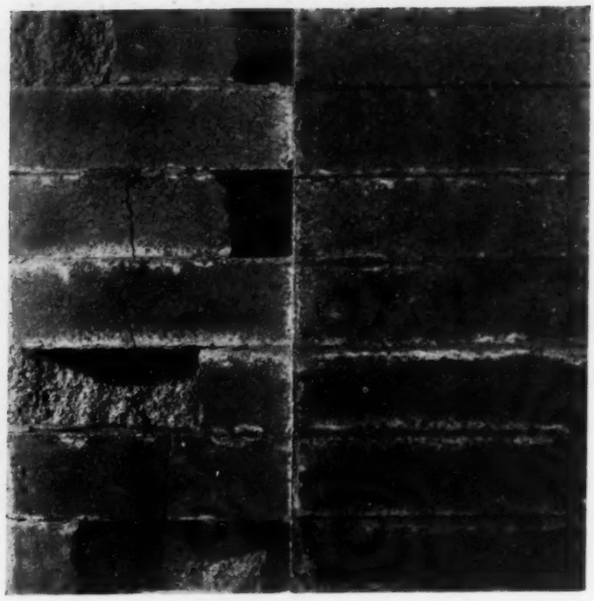


Fig. 7—On the left are shown some burned chrome improved by the addition of magnesite. These, after 20 cycles of heating and cooling, lost 12 per cent in weight. On the right are shown the Ritex-Chrome brick, which show no loss after the same treatment.

for regular burned chrome brick 0.30. In other words, the burned brick allowed gas to pass more than 160 times faster than the Ritex brick.

Sillimanite Brick

Sillimanite brick, being produced in increasing tonnages each year in standard sizes and shapes, should be pointed out, in spite of their present high price, as a refractory offering properties which have been found to be of value in special installations in the steel mill. Real impetus to the manufacture of these refractories is due to the availability of a special Indian cyanite ore occurring as dense, hard, massive boulders shown in Fig. 9 which can be ground to any desired grain size and dry pressed. Sillimanite brick are nearly 100 per cent crystalline and closely approach silica brick in their ability to carry loads at high temperatures. They possess a very high resistance to spalling, however, not shared with silica. High melting point, high bulk density, and volume stability are other desirable properties.

A variation of these brick, of the same approximate crystallinity but of a composition about half mullite and half corundum is the electrocast product of the Corhart Company. The electrocast brick are further characterized by practically an entire lack of voids. While price and previous inability to cast other than large blocks have been deterrents in the extension of the use of these products for steel mill furnaces it is worth pointing out that skill in electrocasting has progressed rapidly and hollow recuperator tile, as well as many other intricate shapes, are being made successfully.

(1) G. B. Wilkes, Jour. Amer. Cer. Soc. 1933, Vol. 16, No. 3.

(2) E. E. Pressler, Jour. Amer. Cer. Soc. 1924, Vol. 7, No. 3.

Silica Brick

The manufacturers of silica brick have spent a great deal of effort in the last number of years attempting to improve this well known product. As pointed out before, many of the possibilities in the properties of this refractory were anticipated early because of the well established fundamental properties of silica. However, attempts to improve the bond and make the brick more spalling resistant by increasing the tridymite content as well as efforts to raise the refractoriness by the use of fluxes other than lime, to date have not resulted in any practical innovations. Dry pressed silica brick are being offered the trade. Further service data are necessary before arriving at conclusions as to their relative worth.

Super-Duty Fireclay Brick

In view of what is now known concerning the volume stability of the fireclays from various producing districts, from long time heating tests, it is possible for the refractories manufacturer to set up as his objective what might be termed the ideal fireclay brick. This would represent the ultimate in development, using the best fireclay and applying the most skilled processing of which the industry is capable.

Such a brick would probably have the following properties:

Alumina	44% Min.
Total Fluxes	2.5% Max.
P. C. E.	34 Min.
Open Pores	10% Max.
Weight of 9" Straight	9 lbs.
Linear Change on Reheating at 1600° (2912°F.)	None
Spalling—Water Dip Test, or Panel Test of the A. S. T. M.	None
Workmanship	No crazing, cracks, warps, or twists, and meeting all tolerances on all dimensions.

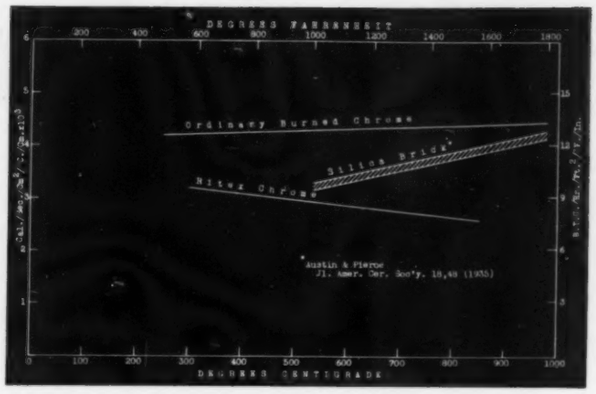


Fig. 8—Thermal conductivity test data comparing both regular burned chrome brick and Ritex-Chrome.

Actually, some of the so-called super-duty fireclay brick now being produced make a good approach to this specification, and represent the highest point to date in the development of the strictly fireclay brick.

These brick are characterized by high density and volume stability, which contribute to increased slag and spalling resistance. The high spalling resistance in the A. S. T. M. panel test is illustrated in Fig. 10. On the left are shown super-duty brick and their condition is to be compared with a good brand of first quality or high heat brick shown on the right. The first quality brick after the test had lost about 18% of their weight. For special purposes these super-duty brick are fired to about 1530°C (2786°F.) and develop very unusual load bearing qualities. These brick, in spite of this very hard burn, are extremely spalling resistant and when given the A.S.T.M. panel test with the preheating temperature raised to 1650°C. (3002°F.) still show less than 1% loss. The development of the super-duty brick was made possible by the use of special flint clays in which incipient vitrification develops only at very high temperatures, plus the application of improved manufacturing methods.

Fireclay Brick

A general improvement in first quality or high heat duty fireclay brick has resulted by the elimination in part or in whole, of the nominal plastic bond clay, which is generally lower in refractoriness than the flint clay constituting the body of the brick. The elimination of this low grade clay made feasible in some cases by the use of the de-airing process and other modern processing methods and a better knowledge of the burning behavior of the flint and semi-flint clays, has made it possible to produce fireclay brick of increased refractoriness, spalling resistance, and freedom from shrinkage. The brick are also harder, stronger, and denser, though it was formerly thought that the last group of properties could be produced to the highest degree only by the use of low refractory clays.

Fig. 9—Special Indian cyanite ore. This can be ground to any desired grain size and dry pressed.

Insulating Fire Brick

In line with attempts to reduce fuel costs, attention to furnace insulation has been responsible for the addition to most refractories manufacturers line in the last year or so of the insulating firebrick. These brick, suitable for lining the interior of certain furnaces, have been developed by inducing high cellularity and proper strength in refractory clays and other minerals.

The cellularity of the mass in the commercial processes now in use is accomplished in a variety of ways, such as (a) burning out a carefully sized combustible like sawdust or cork, (b) vaporizing at drier temperatures a volatile organic material such as naphthalene, and (c) combining gas bubbles with a finely ground plastic mass or slip. The bubbles may be produced by mechanical aeration; or by gas from a chemical reaction of certain batch constituents, followed in either case by stabilizing the foam so generated.

Most efforts to date have been directed toward producing brick with as high a thermal resistance as possible without too much sacrifice in strength, the latter being generally directly proportional to the bulk density of the product. The value of the latter for fireclay insulating firebrick as shown by Bole (1) ranges from 40-50 lbs./cu. ft. and the K value from 1.1—1.3. Diatomaceous earth brick at one extreme, have a density of about 35 lbs./cu. ft. with a K value of about 1.0, and regular commercial firebrick at the other extreme with a density of nearly 130 lbs./cu. ft., have a K value of about the order of 3.0. It is probable that the same relationships will hold at furnace temperature, since at least for clay refractories the K value rises almost as a straight line function of the mean temperature. In general the average insulating firebrick will be found to have about one-third the density and thermal conductivity of ordinary fireclay brick.

Two other critical properties of these refractories are the shrinkage and spalling at furnace temperatures. Both properties are more exaggerated than in the usual refractory. The shrinkage is dependent partly upon the clays used and the thin cell walls of the product. The spalling tendency is related to the low conductivity which sets up steep heat gradients and accompanying high stresses in a body of naturally low mechanical strength. This can be offset to some extent by inducing a certain degree of elasticity, by properly designing the mix. The first of these brick marketed were recommended for furnace temperatures of not over 1400°C. (2552°F.) but now brick recommended for service up to 1650°C. (3002°F.) are available. These

(1) Development of Light-Weight Clay Products by G. A. Bole, Bulletin No. 84, Ohio State University Eng. Exper. Station, Page 25.

recommendations are based at present on the amount of shrinkage shown in comparatively short laboratory reheat tests of 5 hours. The brick probably should be reclassified on the basis of laboratory or service tests of much longer duration.

APPLICATION OF IMPROVED REFRACTORIES IN FURNACE CONSTRUCTION

Blast Furnaces

Specially treated fireclay brick are used exclusively and there is hardly any other application in which clay brick must combine to such an extreme degree the properties of proper burn, high density, hardness, high strength, high refractoriness and excellent workmanship.

To attain this unusual combination of properties it has been necessary for the manufacturer to thoroughly investigate the properties of available raw materials and the possibilities of the various manufacturing processes. The investigation of raw materials has brought forth some very interesting information. A brick to be relatively free from shrinkage in service must be processed so as to be as heavy as the clays in it will permit. With this in mind it is evident the raw and fired properties of the clay will, to a major extent, determine the ultimate properties of the finished brick. For instance, of the three major clays available for the manufacture of blast furnace brick, one will not burn to a dense structure. The result is a relatively lightweight brick and ultimate shrinkage in service. Of the two remaining that will burn dense and produce heavy non-shrinking brick, one is low in alumina and very light in weight in the raw state, requiring a very high shrinkage upon firing to produce a heavy product. This high shrinkage is accompanied by cracking and warping and the finished brick does not possess the good workmanship necessary for a tight accurate job of bricklaying.

The remaining clay is high in alumina, heavy in the raw state and fires to a dense structure, thus producing a brick that is highly refractory, of good workmanship, dense and non-shrinking.

The use of such a clay, combined with the improved methods of processing and firing, results in the improved blast furnace refractories available today.

Hot Blast Stoves

The two factors which most affect the properties of refractories for stove construction are: (1) "Cleaner" gases, and (2) the more extended use of specially designed checkers.

The "cleaner" gas contains less entrained solids and "plugging up" of top checker courses is not now so common. However, the clean gas still contains a relatively large percentage of alkalies which penetrate a porous brick. This alkali penetration shows up as extensive shrinkage or spalling in combustion chambers, domes and top checker courses. The result is a demand for a dense brick that will not absorb alkalies.

The special checker designs, often very difficult to make, must be of excellent workmanship, as well as dense and refractory, to resist the alkali penetration referred to above. The knowledge gained in improving blast furnace brick has been applied to stove brick problems and the stove brick available today, even to the special checkers, are dense, more refractory, and better in workmanship than those on the market only a short time ago.

In combustion chambers and domes, brick life can be considerably lengthened by laying and coating brickwork with a properly prepared sillimanite cement. Fig. 11 illustrates a sillimanite cement coating trowelled both $\frac{1}{16}''$ and $\frac{1}{4}''$ thick on a clay brick and fired in a long soaking heat to 1475°C (2687°F.). There is no fusion, cracking or peeling.

Where only small standard sizes are required, super-duty clay brick offer some promise of displacing the better known clay brick.

For complicated shapes, properly processed cyanite or sillimanite offers considerable promise.

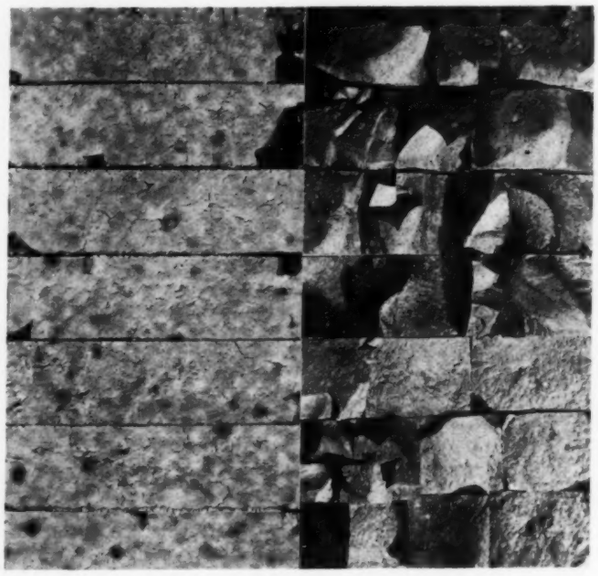


Fig. 10—On the left are shown super-duty brick and their condition is to be compared with a good brand of first quality or high heat brick shown on the right.

Hot Metal Cars and Closed Ladles

Most of the short runs or poor lining life in car type hot metal ladle cars has been due to one or more of the following factors: (1) improper design, (2) shrinkage in the brick making up the lining, (3) use of improper or low grade mortar in laying up the brick.

Improper design is essentially the use of shapes or sizes which cannot be manufactured in dense, volume stable refractory material, resulting in shrinkage, and hence, open readily eroded joints. Shrinkage of the brick, if the lining is properly designed, is due to lack of density or insufficient refractoriness. Improper mortar is that which lacks refractoriness, or resistance to slag, or shrinks when the ladle is fired or charged with hot metal. The beneficial results of volume stable brick and good mortar have been amply demonstrated in the case of 150 to 160 ton car type ladles. The original linings had the initial advantage of good de-

sign, but the life was considered unsatisfactory. The substitution of volume stable brick and the use of a carefully prepared sillimanite mortar instead of fireclay increased the lining life from 50,000 to 115,000 tons, with a decided reduction in refractory cost per ton of iron handled. In fact, the ultimate cost per ton was decidedly under any cost previously attained on any type of lining.

In the case of open top ladles using ordinary ladle brick that are subsequently converted to closed top, the above job described for car type ladles is also a decided economy.

Mixers

Mixer linings are subjected to much the same service conditions as car type ladles, except they are not usually subjected to so much intermittent heating and cooling. In those mixers not handling particularly hot metal, a lining such as that described for the car type ladles will do good work. However, the use of basic brick, particularly Ritex-Magnesite laid in high grade chrome-magnesite bonding mortar, is rapidly spreading. Of the basic refractories, Ritex-Magnesite brick are particularly applicable because of their high resistance to spalling.

Basic Open Hearth Furnaces

Probably the most varied and specialized uses for refractories in any of the steps in steel making occur in basic open hearths. Further, because of the large number of furnaces always in operation and their importance in the quality and cost of steel, attention is constantly being focused on the selection and improvement of the refractories going into their construction.

Roofs at present are constructed entirely of silica brick. Silica brick, despite their acid nature, give good service under most present day operations, essentially because of their crystalline nature, ability to carry heavy loads at high temperatures, and low cost.

A good many insulated silica roofs are in use and some operators claim an appreciable increase in roof life from this cause. Harvey (1) and Miller (2) have both observed an effect with insulation which may be one explanation for increasing roof life. Both investigators found that the so-called "weak zone" of silica brick is either lacking or so dispersed as to be ineffective in weakening the brick. Harvey made his observations on an 18″ roof brick covered with 4″ of expanded vermiculite insulation which closely follows current practice. Lowered heat gradients through the brick may also aid in reducing spalling losses and thus lengthen roof life.

Buell (3) in his analysis of the effect of insulation on silica open hearth roofs points out the limiting thickness of roof brick, which he establishes at 13½″, below which it is not safe to insulate, except with great caution as to the thickness and type of insulation. Experience with both 9″ and 12″ roofs to date, however, seems to be uniformly satisfactory with respect to refractories life and would indicate that proper consideration is being given to type and thickness of insulation.

Any increase in finishing temperatures is likely to force consideration of a basic brick for roof construction. The present availability of a basic brick having low thermal conductivity and high resistance to spalling and the success of basic roofs in the Copper Industry brings the solution of the problem somewhat nearer. The ultimate basic roof will likely be suspended. Successful results with basic roofs on steel furnaces have already been obtained in Germany.

In the exposed sections of the furnace above the floor level consisting of front and back walls above the slag line, uptakes (downtakes), bulkheads and ports, silica brick, despite their acid nature, are widely used. These portions of the furnace deserve serious consideration in any campaign to save fuel or reduce refractory costs where service conditions are unusually severe. As a substitute for silica brick in these parts of the furnace, Ritex-Chrome brick possess the following outstanding properties: (1) lowest thermal conductivity of any basic brick; (2) freedom from shrinkage; (3) elimination of silica wash so detrimental to banks; (4) sufficient refractoriness to permit insulation or elimination of most water cooling; (5) high resistance to spalling; and (6) sufficient density to prevent air infiltration. To get maximum service from Ritex-Chrome in the exposed sections of an open hearth furnace, they should be laid in thick joints (¼″) of specially prepared chrome-magnesite sodium silicate-free high temperature cement. This cement does not increase the original cost of the brickwork and the thick joints virtually eliminate the necessity of normal provision for thermal expansion. This mortar further tends to give a tighter brick job.

Below the floor level in substituting basic brick for silica, it is often advisable to carry the basic brick well down into the slag pockets, generally to the slag pocket arch.

Checker brick for open hearths should have high heat capacity and high density. There is the additional factor of high salvage value. The same improvements in hot blast stove checkers are available in open hearth checkers and since the latter are simpler in design, the open hearth furnace offers greater opportunity for more extensive use of super duty brick. The latter, because of their high refractoriness, offer decided salvage possibilities. Since the dusts accumulating on and attacking checker brick are highly basic, the use of a basic brick is indicated and some tests have already been conducted. These tests have shown that Ritex-Magnesite brick possess the necessary physical properties to withstand a campaign without cracking or spalling. They further have 40% more heat capacity than clay brick. The only drawback has been a tendency for the dust to build up on itself (not by attacking or attaching itself to the brick) and eventually plug up the checker openings. Some "Well design" or other type of construction which would permit free flow of gases, would

(1) F. A. Harvey, "Comparison of used Silica Brick from Insulated and Uninsulated Basic Open-Hearth Roofs". Journal American Ceramic Society, 1935, Vol. 18, 86-94.

(2) Lewis B. Miller, "Effect of Insulation on Silica Refractories of an Open Hearth Furnace Roof". Bul. Cer. Soc. 1935, Vol. 14, 359-364.

(3) Wm. C. Buell, Jr. "Insulation and Control of Open-Hearth Furnaces". Metals Technology, August 1935, Tech. Pub. No. 641, A. I. M. M. E.

Fig. 11—Sillimanite High Temperature Cement. Test after long heating to 2687°F. Showing no fusion, cracking or peeling.

eliminate this trouble and probably establish Ritex-Magnesite brick as an outstanding checker refractory. Fig. 12 shows the comparative appearance of Ritex-Magnesite (two inside rows) and a super duty grade brick after a year in a glass tank checker chamber where the dusts are also basic. The Ritex-Magnesite has not taken on a coating and the bulk of them can be salvaged for another campaign.

Tap hole construction has been considerably simplified by the use of dense, hard, joint-free shapes of very excellent workmanship made by the Ritex process. Tubes or cylinders for building tap holes are available in lengths conveniently handled. One size regularly used is 24″ long with an inside diameter of 7″ and an outside diameter of 16″. A tap hole constructed of these sections gives long service and uniform flow.

Experiments with ladle refractories and other lining materials continue. Extension of the use of dense refractory non-shrinking high grade clay brick laid in a proper mortar, for open hearth ladles is indicated from the experience with car type ladles. This should be particularly true where insulation is desired. At present a specially prepared sillimanite cement is being used for setting nozzles. The use of this cement in place of clay facilitates the removal of the nozzles and eliminates many inclusions. The same cement is also being used to fillet the junctions of the ladle walls and bottoms, thus preventing skull adhesions to the ladle lining and allowing skull removals without damaging the lining.

Clay nozzles, with their tendency to rapidly erode and contribute to inclusions, can be improved upon. The use of magnesite nozzles in connection with high manganese or extremely hot heats is increasing. These

Fig. 12—Ritex-Magnesite and super-duty brick after exposure to basic and alkaline dusts for 1 year in glass tank checker chamber.

nozzles do not erode. They maintain an even flow from the ladle. Magnesite nozzles representative of those now in use are illustrated in Fig. 13.

Soaking Pits

The refractory requirements which must be considered are essentially those for the covers, side or division walls and slag line at the bottom of the sidewall.

The covers are usually clay brick of sprung or suspended arch construction. The brick ultimately fail because of shrinkage or spalling. Super duty grade clay brick are being more extensively used in place of first quality brick and are giving a good account of themselves. The life of any cover, particularly that of

Fig. 13—Magnesite nozzles for pouring steel.

suspended construction, can be increased if the brick are laid in and coated with the proper cement. It is reported that at least one test of insulating fire brick is under way.

The side or division walls are built of clay brick, some of natural sand stone and some of the Yough type silica brick, depending upon service conditions. The latter is most widely used. Where particular service conditions require clay brick, the super duty grade does the best work.

The slag line is built of chrome or magnesite brick. Attempts to use super duty clay and high alumina brick have generally failed. Of the chrome and magnesite brick the Ritex type, because of their high resistance to spalling and great density, are very widely used.

Billet or Slab Heating Furnaces

These furnaces include the "continuous" and "intermittent" (in and out) types. The bottoms may be constructed so that the billets rest either on water cooled skid pipes or directly on solid refractories.

Spalls or fragments of brick from the roof, if they fall on the billets, can cause considerable trouble as inclusions. For this reason a great deal of attention must be paid to the selection of roof brick. Roofs are of both sprung and suspended arch construction. If the furnace is steadily operated and kept above red heat, silica brick give the most satisfactory service. If the furnaces are frequently cooled, as are the majority, silica brick cannot be used and some other roof brick must be chosen. First quality fire clay brick have been widely used, but in the hottest area do not give satisfactory service. The same applies to high alumina brick. Both of these types, where oil or gas is used as fuel, tend to shrink, crack and spall. The tendency at this time is toward a more extended use of super duty brick, both clay and kaolin. All roof brick should be laid in and lightly coated with a refractory non-shrinking cement preferably with a sillimanite base.

The service on sidewall brick is not as severe as that on the roof brick and representative first quality fire clay brick are generally satisfactory.

Bottoms where refractories are required are usually built of a plastic chrome ore preparation. These are rammed or tamped in place to a depth of four to five inches. Such bottoms are dense and hard and chemically neutral, except for those furnaces operated at unusually high temperatures.

In some furnaces considerable trouble has been experienced with the brick forming the piers supporting the water cooled skids. These piers are heated on all sides, subjected to some roll scale coming off the billets and have to carry a fairly heavy load. Clay brick have been most generally used but rapidly cut away. Burned chrome brick have been tried but they usually spall or sluff away. Silica brick have been suggested and may be tried. The most suitable refractory, everything considered, may be found to be a brick of the sillimanite type.

DISCUSSION

PRESENTED BY

GILBERT SOLER, Manager of Research, Timken Steel & Tube Company, Canton, Ohio.

LOUIS A. SMITH, Refractories Engineer, Jones & Laughlin Steel Corporation, Aliquippa, Pa.

M. J. CONWAY, Fuel Engineer, Lukens Steel Company, Coatesville, Pa.

GILBERT SOLER: The author has presented in a complete and concise manner a description of refractories manufacture and utilization. The description of the processes of manufacture, the raw materials available, the physical characteristics of the finished product, and its use, are all important to the consumer of refractories. If those who are in the steel industry knew more of refractories from the manufacturing stand-point, less abuse and misapplication of refractory products would result.

It may be stated that future refractories developments will not be limited by availability of raw materials which can be converted directly into the finished product.

Mixing these raw materials synthetically to produce new refractory compounds opens a wide field of development. Such compounds can be produced in a preliminary firing treatment such as is now used to calcine the grog (inert portion of the refractories). The resulting material, being largely crystalline, could be properly bonded, and therefore refractory shapes with desirable physical characteristics could be produced.

LOUIS A. SMITH: This is an excellent paper and I hardly feel qualified to discuss it beyond expressing my heartiest approval. It carries a fairly persistent theme advocating greater use of basic brick and particylarly Ritex brick and it presents several new and perhaps courageous recommendations for increased use of super clay brick and sillimanite cements.

Use of volume-stable brick and sillimanite mortar in ladles involves a radical increase in first cost but the idea sounds reasonable and I believe it might lead us to better ladle life, improved yields of better quality product and ultimately reduced unit costs. We should all see if there is'nt some way we could play with this idea in a smaller way than the complete lining of a 100 ton ladle.

The positive suggestions in the matter of using basic brick in open hearth back-walls with quarter inch joints of a good basic cement brings up a point that deserves more attention in general practice. Too many basic brick are laid without mortar or with not enough mortar and with too little attention to expansion effects. Most steel plants could collect important benefits if more chrome and magnesite brick were laid as recommended in this paper.

Most plants would profit by using better brick in combustion chambers and top checkers of stoves but many are holding back because of troubles that followed previous recommendations for high alumina brick which did not work out so well. Mr. Trostel renders a service in pointing out the benefits that should come from limited and intelligent use of sillimanite cement in domes and combustion chambers.

The contemplation that open hearths may come to basic suspended roofs is not too fanciful for current consideration. I believe this idea will come into practice sooner than some of us suspect and I hope that open hearth people will be stimulated to more than passive consideration of the subject at this time.

(Please turn to page 46)

Refractories Application

THE TREND IN THE STEEL PLANT

By A. V. LEUN, Refractory Engineer
Bethlehem Steel Company,
BETHLEHEM, PA.

Presented before the Annual Convention of the A. I. & S. E., Detroit, Michigan, Sept. 22-25, 1936

▲ THE subject of refractories is one of the most important items involved in the production of steel and its allied products. In every instance from the blast furnace down through the open hearth, refractories form the lining and hearth in which the metal is melted and refined. The ability of these refractory linings to withstand temperature, abrasion, slag erosion, etc., is the governing factor in the ultimate refractory cost.

In recent years, many worth-while improvements have been made both in the manufacture and application of refractories. These improvements were necessitated because of

1. The greater service and temperature imposed on the refractories in the making of steel.
2. The continued drive for cleaner steel.
3. The necessity for lower refractories cost.
4. The necessity for lower fuel consumption per ton steel produced.

In the following pages, the writer will enumerate and discuss those improvements together with the results obtained from such improvements in the continued drive for better refractories and lower cost.

LADLE REFRACTORIES

Almost every ton of steel produced in an open hearth, electric or induction furnace is poured into a refractory lined ladle from which it is later poured into the proper moulds for subsequent rolling or working. All of these ladles are equipped with a stopper rod assembly and seated in a refractory nozzle in the bottom of the ladle and operated vertically by means of a suitable mechanism attached to the outside of the ladle shell. The stopper rod assembly consists of a stopper head held to the bottom of the rod by means of a wrought iron bolt through the center of the head. The entire length of the rod is protected from slag and metal attack by clay sleeves which run from the head to the top of the rod. The flow of steel from the ladle is controlled by the seating of the head in the nozzle, both of which are so designed to allow for the best closing. When bottom pouring is practiced additional refractory shapes are employed to lead the steel as it is poured from the ladle down through a central runner and out to the various moulds set up on the block.

The use of 2nd and 3rd quality sleeves and nozzles and even runner brick had been the practice for years. The stopper head was made of a mixture of clay, grog and graphite, the graphite acting as a conductor of heat, preventing spalling and also improving the refractoriness.

With the advent of more rigid pouring practice, together with hotter and longer pouring, trouble was encountered in excessive erosion of the nozzle resulting in a wide variation in the rate of pour, melting away of the sleeves, burning off of the rod at the stopper head, sticking of the head to the nozzle seat and excessive washing of the runner brick.

The ladle refractory manufacturers were advised of the condition and specifications were placed on such shapes with regard to refractoriness. Instead of using low fusing clay as the bonding medium for such shapes, which clay softened and washed during service, the manufacturers employed a higher refractory clay. In table 1 a comparison is made of the refractoriness of the old and new sleeves, nozzles and runner brick. The improvement in these refractories eliminated a great deal of the trouble formerly encountered. It is to be noted that with greater refractoriness in ladle refractories, the porosity must be lowered to obtain the best results.

TABLE 1

	Temperature of Vitrification	Fusion	Porosity
Old sleeves, nozzles and runner brick..	2350°F	2750°F	18.0%
Improved sleeves, nozzles and runner brick.....	2600	3100	12.0

A. V. LEUN

With the marked improvement, however, in the clay refractories, trouble was still encountered due to the heads often burning off during the pour. The stopper heads and bolts holding these heads were studied and it was definitely determined that the heat flow through these heads during service was so great as to cause softening and ultimate elongation of the bolt, allowing the steel to cut the rod between the head and lower sleeve. In figure 1 is shown a bolt before and after using. Stopper heads suitable for year, no longer gave the service demanded. Stopper heads were produced having a lower conductivity but still containing enough graphite to make them spall-proof. In figure 2, is shown a representative curve through the same sized head ($5\frac{1}{2}''$) having lowered conductivity. The heads produced with lowered heat flow immediately eliminated the burning off of the bolts in stopper heads. This new type of head is in use today and its purchase is controlled by a rigid heat flow specification. We feel that this improvement in stopper head manufacture was one of the most important effected in many years in that it was a radical departure from the old theory of head construction.

Reference is made by the writer to an article published in the June 1932 issue of the Blast Furnace & Steel Plant magazine on this subject.

No reference has been made to ladle brick inasmuch as this class of ladle refractory must be of comparatively low refractoriness to give maximum life. Ladle brick are exposed to the molten metal and slag only on the inner face and to maintain themselves in the ladle, they must swell or overfire below the steel temperature. This swelling keeps the joints tight and prevents metal or scull penetration into the joints, which would cause failure of the lining.

INSULATION OF OPEN HEARTH FURNACES

The insulation of open hearth furnaces, especially above the floor is comparatively new. Ten years ago, it was the almost universal opinion that an insulated furnace would be melted down in a few heats. In fact, there are those today who still profess to this belief, notwithstanding the fact that in many plants open hearth insulation is a recognized success.

By insulation of an open hearth furnace not only is radiation of heat from the furnace walls retarded but air infiltration is greatly minimized. The effect of these two factors is to increase the hot face temperature of the furnace lining. However, since this face temperature must not be increased, a decrease in fuel input is necessary. This fuel saving will run from 10 to 20 percent, depending on the operation and conditions of the furnace before being insulated.

For economical furnace life, in respect to refractories, it is most important that the operating hot face temperature of the roof be maintained at that temperature employed on the uninsulated furnace. In many furnaces where the uptakes are small, the application of insulation to the ends is not recommended due to the scouring action of the outgoing gases causing early end wall failure. In furnaces having large downtakes, insulated end walls of silica brick require no repairing during an entire campaign.

After Before COURTESY OF VESUVIUS CRUCIBLE CO

Figure 1—Stopper head bolt before and after use.

The open hearth roof can in all cases be insulated. As a factor of safety, many Open Hearth Superintendents install roof temperature control to aid in controlling the hot face temperature of the roof. The application of insulation to an Open Hearth roof, besides its saving of fuel, seasons the silica brick to a far greater extent than in an uninsulated roof. In figure 3, is shown silica brick taken from an uninsulated and insulated furnace roof. In the brick removed from the uninsulated roof, four zones are very apparent. The first zone is composed of practically all Cristobalite with some magnetic iron in the interstices. This zone is highly refractory. The second zone is black in appearance being impregnated with magnetic iron carried into the brick by capillary

action from the furnace. This second zone contains a high percentage of tridymite as it is the stable form of silica at the temperature of that zone. This zone is some 40°F lower in refractoriness than the first zone. The 3rd zone is comparatively narrow and is the least refractory of all.

The calcium-aluminum-silicates are driven out of the first and second zones due to temperature and into the third zone. This zone moves back as the roof wears away. The fourth zone is unchanged. Comparing this brick with that taken from the insulated roof, we find the first zone instead of being ½″ thick is 3 to 4 inches thick, the second zone is practically the remainder of the brick, while those impurities normally found in the third zone are driven out of the brick into the insulating medium on the roof. The greater refinement of the brick in the insulated roof as indicated by the thickness of the first zone plus the greater resistance of the brick to spalling is responsible for the increased life of such insulated roofs. In one of our open hearth departments in the Bethlehem plant, where complete furnace insulation has been in effect since 1932, the furnace roof life has been increased from an average of 225-250 to 465-480 heats per roof. We have had several roofs go over 525 heats. These furnaces are of 110 ton capacity and oil fired and are equipped with roof temperature control.

Many materials are employed in the insulation of open hearth furnaces. However, it is not within the scope of this paper to pass on their quality. We employ an insulating cement made with slag wool as a base for our end walls, bulkheads, etc., it is aplied in monolithic form 3 inches thick. For roof insulation, our practice is to employ 1½″ silica sand next to the roof then 1½″ silica sand and 25 percent cork and finally 1 to 2″ of slag wool cement as a plastic coating. This

Figure 2—Heat flow curves showing graphically; "A"—Regular stopper head—"B"—Stopper head corrected for lowered heat conductivity.

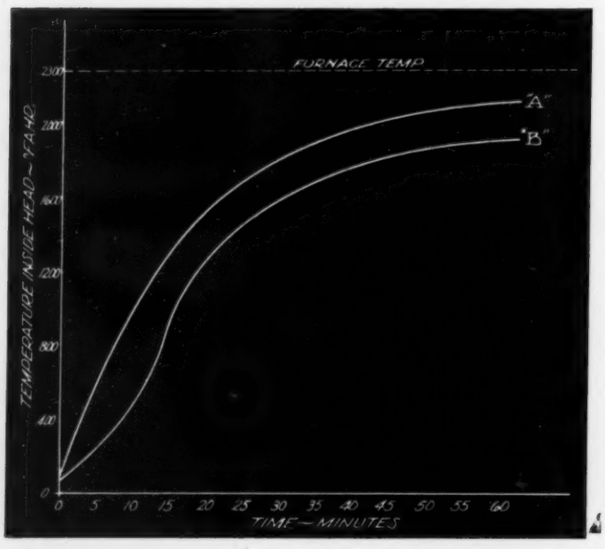


FIG. 3
SILICA BRICK TAKEN FROM
A—INSULATED OPEN HEARTH ROOF
B—UNINSULD OPEN HEARTH ROOF

application of insulation is so applied that when parts of the roof wear down to five inches in thickness, there still remains sufficient strength to maintain itself. Too much insulation would mean too high a mean temperature with possible roof collapse in thin sections.

In this discussion, the insulation of the regenerator chambers and flues has not been considered since this phase of insulation was generally accepted a number of years ago.

I recommend the application of open hearth furnace insulation to the extent possible, in all cases including the roof. With a little care on the part of the operator, the fuel saved will be at least 10 percent besides giving a greatly increased roof life.

Those operators who have experienced failure in their attempts at open hearth furnace insulation have probably either applied too much material, the wrong material or have failed to reduce the fuel input to the extent necessary.

Additional information on this subject may be obtained from Bulletin No. 23 of the Carnegie Institute of Technology of 1925 and from a paper presented by Mr. E. F. Entwistle at the 1933 meeting of the American Iron and Steel Institute.

CHROME AND MAGNESITE BRICK

Over the past 5 to 6 years, great strides have been made in the manufacture of basic refractories. Today chrome brick have been so perfected that their application has become much more diversified than heretofore. By heat and chemical treatment, these brick have had their load carrying ability raised approximately 300°F and have become more resistant to slagging and spalling.

Both unburned Magnesite and Chrome brick show only negligible volume change at working temperatures. Made under pressure as high as 10,000 pounds per square inch from a carefully sized aggregate, these brick have greater density than ordinary burned brick giving them better resistance to slag erosion and spalling.

INSULATING REFRACTORY BRICK

In the past, insulating brick have been considered only in the light of back-up brick for fireclay or other refractory brick for the purpose of decreasing the heat loss through such firebrick walls to the surrounding air, but increasing the heat content of these walls by raising the mean temperature of the walls.

Several years ago a new idea in insulating brick was introduced; namely light weight refractory brick. These brick have fairly low conductivity value and also possess suitable refractoriness to allow their use in actual contact with furnace temperature. There are brick in this class capable of use at 2850°F.

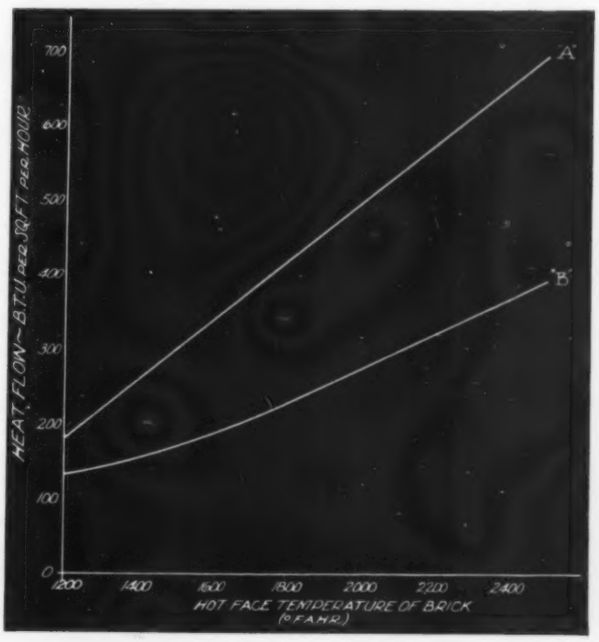
Light weight, insulating refractory brick, while suitable for many types of furnaces, are especially adaptable to those furnaces whose operation is intermittent. Since their density is from 35 to 50 pounds per cubic foot as compared to 120 to 130 pounds per cubic feet for fireclay brick and since heat content is proportional to density, it is apparent that these refractory insulating brick will absorb only from 25 to 40% of the heat absorbed by fireclay brick. As these brick possess low heat content, their use in a furnace will decrease, by not less than half, the time required to bring the furnace up to operating temperature. Once at operating temperature, having low conductivity, such brick will retard the heat loss through the wall to a far greater extent than fireclay brick. To illustrate this point, let us assume we have two furnaces, one built of 13½" fireclay brick, backed up with 4½" of insulating brick. The other furnace is built up of 9 inches of insulating refractory brick backed up with two inches of block insulation. Both furnaces contain the same charge and must be brought up from air temperature to 2200°F. Instead of giving dimensions, let us assume that the interior furnace area equals 800 square feet. Let us further assume that coke oven gas is the heating medium and cost 25 cents per million B.T.U's. Now referring to figures 4 and 5, the following data is obtained.

	Firebrick Construction	Insulating Refractory Brick Construction
1—BTU's required to bring furnace up to operating temperature/sq. ft.	72,000	9,200
2—BTU's Req. per total fce.	57,600,000	7,360,000
3—BTU's lost (sq. ft.) hr. by radiation	575	320
4—Heat loss from total wall surface	460,000	256,000
5—Heat loss per 10 hr. operation	4,600,000	2,560,000
6—Total BTU's expended	62,200,000	9,920,000
7—Cost of Heating and operating 10 hours	$15.55	$2.48

8—Saving in fuel by use of insulating refractory brick for one cycle of furnace = $13.07

Insulating refractory brick are applicable to any furnace, providing the temperature does not exceed the safe working temperature of the bricks and no slag is present. While as high as 75 percent of heating up time may be saved by the use of this class of brick, it is not recommended that the maximum rate of heating be carried out as a safeguard against spalling of the refractory. Since insulating brick do not absorb ap-

Figure 4—Heat flow curves showing graphically; "A"—13½" fire clay brick and 4½" insulated brick wall. "B" —9" insulated refractory brick and 2" insulated block.



preciable heat, the surface of these brick will heat up at a much higher rate than would fireclay brick. Too rapid a temperature rise will ultimately impair the value of such brick.

Insulating refractory brick should have certain properties to insure their most satisfactory service.

1—They must be fired at a temperature higher than their operating temperature.
2—They must be reasonably spall resistant.
3—They must be able to take a coating and to hold it during use.

When laying insulating refractory brick, it is important that they be laid and sprayed with an air setting high temperature cement to seal the walls against gas filtration through the permeable brick. In addition, the application of a semi-glazed surface on the brick will aid in reflecting back into the furnace some radiant heat which would normally pass into and through the wall.

Summing up the advantages in using Insulating refractory brick:—

1—They are easily laid.
2—Thinner furnace walls can be employed.
3—Fuel savings of at least 25% can be realized by their substitution for fire brick. This saving being influenced by the operating temperature of the furnace.
4—The conductivity K is approximately one-fourth that of firebrick.
5—Less weight to support.

SEMI SUPER REFRACTORY CLAY BRICK

The refractories industry has always produced first, second and third quality brick as well as those refractory brick classed as high alumina. However, due to the demand for greater production, the application of external insulation, the use of higher working temperatures and the continual drive for cleaner steel, first quality brick whether hand or machine made failed to give the life formerly obtained in many furnaces. With this decrease in life came an increased danger of the refractory producing inclusions in the steel.

To meet this demand, the brick manufacturers, after considerable research, introduced brick referred to as Semi-Super Refractory Brick. These brick are in most cases made in Missouri and besides being made of sized particles, have little or no low fusing bond clay, which is generally employed in ordinary first quality clay brick. In comparing fireclay brick, the fusion point of the brick is not the yardstick to use in classifying them for serviceability under furnace temperature. The vitrification temperature or the temperature at which any part of the refractory body softens is the important one. No matter how refractory the grog or flint clay in a brick may be, the bonding clay softening will cause ultimate failure of the brick, either by spalling or by collapse due to temperature and load.

A large decrease in porosity of a fireclay brick when heated to a high temperature is indicative of a high content of easily fusible bond clay. The greater this decrease of porosity, the less will the brick stand high prolonged temperature.

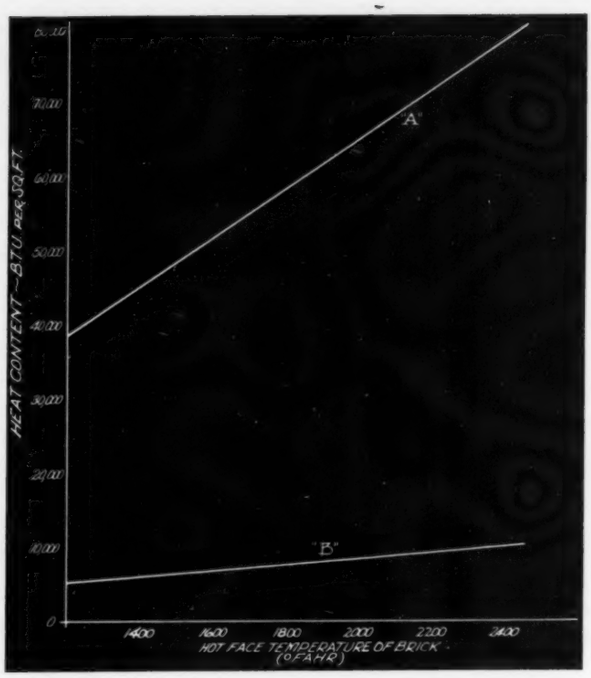


Figure 5—Heat content curves showing graphically; "A"—13½" fire clay brick and 4½" insulated brick wall. "B" —9" insulated refractory brick and 2" insulated block.

A comparison of several of the brands of semi-super refractory brick with a good first quality clay brick is tabulated below:—

Brick	Vitrification Temp.	% Deflection at 2650° F	Change in Porosity at 2650°
1st Quality clay brick	2600°F	7.5%	4.3%
Semi Super Ref. Brick A.....	2725	0	0.7
Semi Super Ref. Brick B.....	2700	0	0.6

In running the sagging test, the brick are placed in a 4½" panel with a 9" dimension extending into the furnace. In this assembly, 4½" of the brick under test are buried in the panel with the other 4½" extending into the heat, and are exposed on all four sides and the end. The outside of the panel is covered with a 2" coating of insulating cement. After being placed in position, the panel is brought up to 2650°F in six hours and then held at that temperature for twelve hours. At the end of the soaking period, the panel is allowed to cool. The amount of bending or sag in the brick due to the temperature is measured and expressed in percent relative to the 2½" dimension.

From the above data it is evident that the semi-super refractory brick will stand temperature better than will first quality fireclay brick and it is also very

evident that the characteristics of the semi-super brick will not be altered at as low a temperature as will fireclay brick. The greater refractorieness of this comparatively new field of fireclay brick makes the brick applicable in such places as:—forge and heating furnaces, kilns, blast furnace stoves, open hearth checkers, boilers, electric furnace covers, etc. By their proper use, a cheaper over-all operating cost will result.

DE-AIRED FIRECLAY BRICK

The use of a first quality fireclay brick, in checker chambers of open hearth and blast furnaces stoves is general practice.

Heat flow through a fireclay brick is dependent on such items as the following:

1—Sizing of particles
2—Fineness of bonding clay
3—Distribution of bonding clay in matrix
4—Density of unfired brick
5—Degree of burn of brick

Eliminating items 1, 2 and 5 inasmuch as they are pretty well standardized there remain to be considered the distribution of the bond clay in the matrix and the density of the brick.

The pugging of a clay-flint mixture, with sufficient water added to make the clay plastic, will more thoroughly distribute the clay over the flint particles than would mixing of the two ingredients in a pan with only enough water added to dampen the material.

Studying a brick from a heat passage standpoint it is made up of air spaces, particles of flint clay and a vitrified bond clay. The air spaces are not conductors of heat but really insulators against heat flow. Therefore for maximum heat transmission through a brick we must have maximum locking of flint particles by means of vitrified clay and a minimum of air spaces. In addition there should be a continuity of particles to allow for heat passage in or out of the brick.

The permeability or the ability of air to pass through a brick is an indication of the pore structure and arrangement of the flint particles. The greater the resistance to air flow through the brick the more heat efficient will the brick be in regenerator service.

Recently de-aired clay brick have been introduced to the trade by the refractories industry. The use of a vacuum during the forming of the brick affects only the density of the brick. However, by the de-airing, part of the entrapped air is removed, allowing for a greater weight of refractory per brick. This elimination of air and slight increase in the weight of the brick tends toward still greater heat conductivity, providing other conditions remain the same. The use of de-airing allows for a better and more uniform burning throughout the brick. Because of the increased density and better burning, resulting in better abrasion resistance, the application of de-aired brick has been made to blast furnace linings with good success.

In the following table is shown comparative results on dry press, stiff mud and de-aired still mud brick in regard to density and permeability.

Type of Brick	Weight	Time required to force 2000 cc of air through brick under 0.5 lbs. Pr.
9 x 4½ x 3 DP	8.75	3.5 minutes
9 x 4½ x 3 SP	9.05	12.5 "
9 x 4½ x 3 SP	9.15 de-aired	14. "

I believe the de-aired fire clay brick will entirely replace the ordinary under-aired brick for use in open hearth regenerators, blast furnace stoves and linings.

POWER PRESSED SILICA BRICK

Silica brick, because of their high expansion when going from Alpha to Beta Cristobalite, are very sensitive to cracking. This expansion occurs between the temperature of 375 to 575°F. When heating an open hearth furnace, care must be taken to bring the roof temperature up at such a rate that the temperature rise in any part of the roof never exceeds 200°F per hour. However, as the heating progresses and as the brick progressively expands from the hot face to the cold one, there is always some section of the roof where a strain is present.

On one side of this section expansion has occurred, on the other or colder side expansion has not occurred. Such a condition causes stresses to be set up between bricks.

The silica brick, as manufactured by the drop or hand rammed method, are not perfectly true throughout their length. Some brick have a slight bow either one way or the other. With such brick in a roof under the conditions described above and with strains in the roof, some will snap off because of point contact between the brick. In some cases, the broken ends will drop out of the roof, others will remain held in place. However, these broken ends will melt away rapidly when the furnace is put into operation.

Power pressed silica brick being free from warps will present surface to surface contact when installed in a roof. The uniformity to size and dimension of these brick will eliminate considerable of the snapping off of silica brick occuring today.

In general, the writer feels that the refractories industry has made excellent progress in the development and manufacture of more refined and serviceable refractories. These improvements were brought about to a large degree by the need of the steel industry for refractories more able to stand the severe service conditions existing in the manufacture of steel.

The refractories producer cannot learn the properties required in a refractory unless the consumer will so enlighten him. In the past many bricks were sold in good faith, only to be the wrong ones for the job. Often the brick manufacturers were blamed for the resulting failures. Close cooperation between the manufacturer and user of refractories will be advantageous to all concerned.

DISCUSSION

PRESENTED BY

L. A. SMITH, Refractory Engineer, Jones & Laughlin Steel Corporation, Aliquippa, Pa.

E. E. CALLINAN, Refractory Engineer, Timken Steel & Tube Company, Canton, Ohio.

A. V. LEUN, Refractory Engineer, Bethlehem Steel Company, Bethlehem, Pa.

L. J. TROSTEL, Chief Chemist, General Refractories Company, Baltimore, Md.

M. J. CONWAY, Fuel Engineer, Lukens Steel Company, Coatesville, Pa.

W. F. ROCHOW, Assistant General Sales Manager, Harbison-Walker Refractories Company, Pittsburgh, Pa.

M. J. TERMAN, Refractories Division, Babcock-Wilcox Company, Pittsburgh, Pa.

L. A. SMITH: In mentioning the fact that users are studying their conditions and passing their findings on to the makers of refractories in the form of recommendations and specifications which are translated into better brick and better practices, the author has touched on one of the outstanding newer developments in the search for refractories that are better fitted for the job in hand. There should be more of this intelligent scientific cooperation between producers and consumers of refractories and there should be more papers from people who use brick. Mr. Leun renders a distinct service in presenting a paper from the steel industry which talks the brickmaker's language.

Using more refractory clays in nozzle manufacture is not new but too many people have for years been trying to correct pouring troubles by charging the size of nozzle opening or by putting fancy curves on the nozzle seat when a little attention to the materials from which the nozzle and stopper are made would have accomplished much more at less cost. From Mr. Leun's statement, one would infer that his 2750 degrees nozzles were mixtures of plastic and non-plastic clays, same as most first quality brick practice. He speaks of substituting a better bonding medium. Many sleeves, nozzles and runners are made of 100% plastic or so called bond clays. Such nozzles have been improved by mixing in better clays which were not necessarily bond clays and others have been bettered by more careful selection of the clays (already in use) which discards small quantities of lower fusing material, thus improving the body. All nozzles are not made of mixtures or blends of plastic and non-plastic clays. 2750 fusion for any flint plastic body seems rather low because any number of plastic clays are used which have higher fusion and the flint clay that is not better than the plastic should not have been used in the first place.

The modification of the stopper head mix to get optimum conductivity and eliminate burning of stopper head bolts is a good point for those who have this problem. Some plants have little or no trouble on this score.

The brief reference to ladle brick is perhaps sufficient in the light of general American practice but we are often told that Europe uses a more refractory ladle brick and gets more heats per ladle than we do. Another author, Mr. J. B. Sullivan, in a recent paper says, "the crying need of the steel industry is a better ladle brick." Mr. Trostel, who also has a paper in this issue, recommends a volume stable brick and sillimanite mortar for certain kinds of ladles. It seems to me there is a positive need for a ladle brick with a much slower erosion rate. I do not think we should accept too easily the prevalent notion that ladles must of necessity be lined with low grade refractories. Old traditions of how poorly some first quality brick did and how much better a poor brick was had best be set aside and some real thought given to developing a better ladle brick for many of today's higher priced more corrosive steels. The same kind of effort that got us better sleeves and nozzles could be applied to good advantage in the matter of ladle brick if our open hearth melters could get away from the notion that our present low fusion ladle refractories are "hard to beat."

The enthusiastic and positive attitude on open hearth insulation is no doubt justified by the author's own experiences but a recent survey of some thirty plants involving more than 200 furnaces shows the industry is far from being agreed on this matter. I believe there should and will be a steady and gradual increase in the application of insulation to open hearth roofs and port ends but there are many things involved besides the reduction of radiation losses. Operators of tilting furnaces have a slag erosion problem over the tapping hole that insulation may aggravate. Most plants, perhaps all should have automatic roof temperature control before they try to insulate. Probably all plants should play with inexpensive but effective sealing against air infiltration before they jump to insulation. I favor open hearth insulation but the operator who has not yet insulated his roofs may not be as far behind the parade as some proponents of insulation would place him. Mr. Leun at Bethlehem has been part of one of the outstanding and economically successful insulation programs in this country; he would naturally be expected to think that every other open hearth roof should be insulated. He may be right in his opinion but there are plenty of plants that had best do some other things before they tackle insulation.

In discussing semi-super-clay brick, the author points out that vitrification temperature, rather than fusion point is a better yard stick for appraising service qualities of refractories. This is an important point which most users and too few brickmakers do not appreciate as fully as they should.

Limitations of this discussion preclude going into detail on de-aired brick but one or two brief thoughts seem in order. With reference to refractories, de-airing

in my opinion, gives us two important advantages. First, in flint-plastic combinations, we can have equal or better physical strength with less bond clay and this helps refractoriness, assuming of course that the flint portion is more refractory than the bond clay. Second, greater density with less p orosity gives two distinct benefits, less damage from penetrating gases, slags or other corrosive agencies and increased heat capacity and better conductivity for regenerative applications. The refractories producers have not particularly stressed the advantage of more refractoriness but they have made some effort to interest the trade in de-aired brick for regenerators. The chief argument for de-aired checkers is the fact that they give increased heat capacity at no greater cost. This increased heat capacity is of no special value to an open hearth where the time travel cycle of the gases is short. The brick will take up more heat but they can't give it back because of the resistance of the air which absorbs heat at practically the same rate with de-aired brick as it did with ordinary brick and all but a negligible part of the greater heat capacity is wasted insofar as improvement in overall regenerative effectiveness is concerned. Further, some of us have found a much reduced salvage value with de-aired brick because of a decided increase in brittleness. With stoves, the longer travel cycle of the incoming air furnishes a better opportunity for utilization of increased regenerative possibilities with de-aired brick. I have no doubt that we will use more and more de-aired brick and I am not ready to argue seriously against their use but I am not able to concur with the author when he predicts that de-aired refractories will eventually entirely replace ordinary un-de-aired brick.

Just a final word on power pressed silica brick. The author approves of them and I share no dissenting opinions but I wish he had seen fit to discuss them a little pro and con. There are still substantial producing units that are not making dry press silica brick and their failure to do so is not a matter of not having the equipment nor their unwillingness to invest capital in new machinery. Further there are sizable groups of consumers who have only recently permitted the use of dry press brick in open hearth roofs and there are still some who will not use them at all. There are important interests among both consumers and producers who argue that power pressed brick spall easier, especially in hot patches. It would have been interesting if the author had dwelt on this subject a little more but in a paper with so many interesting points so well covered, I am not disposed to criticize the curtailed treatment of this topic. I bring this matter up with the hope that Mr. Leun will find a way to give it more attention in some future paper.

E. E. CALLINAN: Mr. Leun's paper should be of distinct interest to all persons who have any connection with refractories, since it presents such a good picture of the consumer's viewpoint of the requirements and functions of refractories. In the past, this viewpoint has been neither expressed nor given the consideration and thought which it merits.

The refractories consumer needs to know, and appreciates, the importance of P.C.E. values, percent loss due to spalling after a certain number of heating and cooling cycles, etc. But just as important from the standpoint of correct application of refractories are data on vitrification temperature, change in porosity under service conditions, and temperature of incipient deformation under load.

Manufacturers could determine these data and pass them on to the consumer by the expenditure of only a little extra effort and expense. Development of improved standardized test methods for the determination of such properties certainly are worthy of consideration. Mr. Leun has not over-emphasized the importance and benefits of such data.

Mention of the use of sand-cork-plastic insulating cement for insulating open hearth roofs attracts interest. It is known that the kind of material used, the amount, and method of application, must be tempered by the consideration of furnace operating schedule, economics, and even the operating personnel. In his paper, Mr. Leun does not give his reasons for the method employed. For example, the bottom sand layer may cause the remaining material to "float" on the roof and thus tend to prevent cracking and consequent decrease in insulating effect, especially if the furnace is subjected to frequent shut-downs, as on week-ends. On the other hand, this sand layer may be used to prevent the other layers from fusing and attacking the silica brick. However, if such were the case, would it not be more advantageous to increase the thickness of the silica roof and then apply the insulating cement to it, directly? Many operators of continuous glass tanks have increased tank life and decreased fuel consumption by increasing the roof thickness.

The conjectures cited above are given only to exemplify why I would appreciate hearing Mr. Leun's particular reasons for employing the practice he mentions.

In this paper, unfired chrome and magnesite brick receive a well-deserved pat on the back. Many have found them more profitable to use than the fired products. Their utility has been determined under a great variety of actual service conditions. However, there may be some conditions under which their advantages over the fired products have not been definitely determined. There is some evidence to indicate that when they are well buried in furnace hearth walls or bottom and remain there for great lengths of time (years) there may be a loss in resistance to metal or slag attack, resulting from the peculiar combination of conditions to which they are subjected in such locations, and over such periods of time. And under the same conditions, some fired products might not suffer so great a loss in resistance to metal or slag attack.

Let it be emphasized that this theory has by no means been proven. But some meager and isolated observations tend to point in that direction. If this is true, it is a good illustration of the fact that one refractory product which is superior to another according to laboratory tests and under many service conditions, may have its disadvantages under certain other conditions and that more painstaking studies of the consumers' problems and experiences are of distinct value to the refractories manufacturers.

Refractories consumers need to express their attitudes

and viewpoints as Mr. Leun has so aptly done in his paper.

A. V. LEUN: The procedure employed in the insulation of an open hearth furnace must be so chosen as to adapt itself to the insulating medium employed. Since slag wool melts at 2350°F., it is advisable to keep it from contact with the roof. The inner layer of sand acts as a filler in case joints should open up. In addition, it will absorb the fluxes from the brick as the heat drives them away from the hot face of the roof, causing a sintering of this layer of sand. Since sintered silica sand is a fairly good conductor of heat, we employ a sand-cork mixture as the next layer. The cork slowly chars away and aids in decreasing the heat conductivity through the sand. Lastly, the wool insulating cement is employed and at no time will there be a danger of flame, etc., causing any melting of this material.

It is much cheaper to follow this procedure than to employ a thicker roof since the cost increases rapidly as the thickness of brick increases.

L. J. TROSTEL: Two important applications of the improved basic brick have not been mentioned by the author, possibly because it was his intention to limit his observations to the practice of the Bethlehem Company. These are (a) the advantageous substitution of magnesite for fireclay nozzles in pouring special steels and (b) the substitution of magnesite and chrome brick for silica brick in open hearth furnace end walls, where silica brick do not give satisfactory performance. Many furnace operators who wish to insulate end walls and find they cannot do so with silica brick, are going to chrome and magnesite brick which can be insulated. These will last in some cases the run of the furnace.

There appears to be some overemphasis on the differences in workmanship possible between drop-machine and hand-rammed silica brick on the one hand, and those made by the dry (power) pressed method. It is possible with care to make silica brick by the first mentioned processes with plane parallel faces and sharp edges and corners. Also, the mere use of the dry-pressing method is no guarantee that the brick so made will always be entirely free from bowing and warping.

A great deal of confusion has existed in the past regarding the nomenclature and the tests which might be applied to determine certain properties of refractories. This condition is undoubtedly due to the great variety of refractory materials manufactured plus the large number of manufacturers and users of the materials. The American Society of Testing Materials, through its Committee (C-8) on Refractories has been interested for a number of years in bringing about a better understanding of these problems by encouraging the use of a standardized nomenclature and tests. It is not suggested that the A.S.T.M. tests should supplant such tests as the refractories engineers in the steel plants have found valuable for their purposes, but it would seem well to use the A.S.T.M. tests where it is possible and so indicate.

With reference to nomenclature, the use of the standard A.S.T.M. definition "Super-Duty Fireclay Brick" might have been better than the author's "Semi-Super Refractory Clay Brick", because he definitely had in mind the former. Admittedly however, the author does well to question the use of the word super in the nomenclature he used.

It would be interesting to those engaged in the testing of refractories to know how the author determines "Temperature of Vitrification" referred to in Tables 1 and 3. This is not a standard A.S.T.M. test and to the writer's knowledge, is rarely determined. Since the test, however, has proven of value to the author in his work, other refractories technologists may at times find it worth while to conduct similar tests, where their facilities permit.

The temperature of "Fusion" given in Table 1 for old and improved brick raises a question as to whether this is a variation of the standard A.S.T.M. Pyrometric Cone Equivalent (P.C.E.) Test though it is not so stated. The latter expression P.C.E. has been suggested by the A.S.T.M. as not only being more descriptive but less confusing than such terms as "melting point" "fusing point" and "softening point".

A. V. LEUN: It has been the author's experience that while the ASTM tests are valuable in the information they determine, they are not suitable in an operating plant where quick results are required and where so many different conditions arise.

To illustrate a problem, let us suppose that a certain runner brick is being eroded by steel when pouring. This runner brick may have a reasonably high melting point and low porosity. A runner brick of another manufacture may have practically the same melting point but its erosion by the steel is negligible. What is the answer? The brick rapidly eroded must soften at a lower temperature or some part of the aggregate must allow for washing by the steel. Such a problem caused our adoption of the test for vitrification temperature and let it be said that in the opinion of the author, it is one of the most valuable in use today.

The determination of vitrification temperature required the sample be ground to pass a 100 mesh sieve and bonded with gum arabic. When dried, it is placed under a platinum ribbon and the temperature of this ribbon is raised to say 2000°F., being held there for three minutes with the aid of an optical pyrometer. The small test piece is then examined for signs of sintering within itself. If no sintering is apparent, the temperature is raised 50°F. and the procedure is repeated. The vitrification temperature noted is that corrected temperature at which the test piece sinters together to form a hard surface under the ribbon, or in other words,—the temperature at which some part of the refractory softens.

In the light of our experience, the fusion point or P.C.E. value, while interesting, is of no value to us. In many cases two refractory bodies may have reasonably close P.C.E. values but their actual vitrification temperatures will be far apart.

We have found this vitrification test which can be run in less than 20 minutes, after the samples are prepared, to classify the brick in much the same order as does the A.S.T.M. load test, which takes many hours.

M. J. CONWAY: Mr. Leun's practical approach to the correct application of refractories in the steel in-

dustry is interesting to the steel plant engineer and refractory manufacturer alike.

Misapplied or poor quality refractories not only add to the cost of heating and melting but can easily affect steel quality after the heat of steel has been tapped.

I was particularly interested in Table I showing improvement in nozzle and runner brick. Can Mr. Leun recommend a composition for a suitable loom or "mud" to be used in setting up sleeves and runner brick in bottom pouring practice?

A. V. LEUN: The bonding medium employed for jointing sleeves and runner brick must possess reasonably high refractoriness but still sinter at a low enough temperature to prevent erosion by the steel. Further, the shrinkage of such material must be held at a minimum.

The writer would recommend a mixture of 60 parts crushed brick to 40 parts of a plastic, high strength refractory clay. Seven percent of liquid sodium silicate plus the proper amount of water should be mixed in thoroughly to bring the mixture to the proper consistency. This mixture will satisfy all of the requirements necessary for best results.

W. F. ROCHOW: The information regarding the insulation of furnaces, which Mr. Leun includes in this excellent paper is especially interesting not only because of the very much wider use of insulating materials for many industrial furnaces during the past few years, but also because of the progress in the development of more diversified types and improvements in the manufacture of brick for insulating purposes. In addition to the very important phenomenon of crystalline inversions of silica brick which are insulated, accounting for their lower spalling tendency, as explained clearly in this paper, the much less abrupt temperature gradient through an insulated roof contributes considerably to this greater spalling resistance.

The importance of temperature control of insulated furnaces is mentioned and of course this point is worthy of emphasis. It is very necessary to take advantage of the insulation by reducing the fuel input in order to prevent premature destruction of the refractories, especially in the case of furnaces which are operated at high temperatures as naturally is the case with the open-hearth steel furnace. With the availability of the several classes of super-refractories, such as the various types of high-alumina brick and super-duty fireclay brick, insulation has become more widely practicable in many kinds of furnaces.

Reference is made to the fact that insulating refractory brick are especially suitable for the construction of furnaces which are operated intermittently. In some instances, with intermittent operation, it has been found preferable to use a construction of fire brick, heavily backed with insulating brick rather than one consisting entirely of the insulating refractory, because of the desirability of maintaining a constant temperature when a furnace charge is withdrawn and a cold one is introduced. When the furnace is built entirely of the light-weight refractories, there is a greater tendency for the temperatures to fluctuate, due to their lower heat capacities. Naturally in the case of a furnace in which the walls are subjected to any abrasion, scuffing, ash deposit or the action of volatile fluxes, the benefits derived from the use of light-weight refractories are offset by the expense of maintenance. For such conditions an insulated firebrick wall frequently is the more economical construction. A word of caution regarding the use of air-setting high temperature bonding mortars for laying insulating refractory brick might be in order. There have been a number of experiences in which these brick were damaged as a result of the drying shrinkage of the air-setting cement with which they were laid. As a result of the impregnation of the insulating refractory by the mortar, due to the very high porosity of these brick, the surfaces of the brick scaled off to a depth of as much as a quarter inch. The mortars manufactured especially for laying and coating the insulating refractory brick, generally serve the purpose better. A coating of the special mortar on the inside of the wall built with brick of this kind is especially desirable for the purpose of retarding air infiltration and the flow of hot gases outward when a positive pressure prevails within the furnace.

The brief information regarding the chemically bonded magnesite and chrome brick explains, among the other desirable properties, the relatively better resistance of these refractories to spalling. The use of the steel container especially with the chemically bonded magnesite, very materially enhances this lesser spalling tendency, for many applications.

The nomanclature "Semi-Super Refractory Brick" quite accurately describes this class of brick and is entirely obvious to those familiar with this type which has been defined by the American Society for Testing Materials as Super-Duty Fireclay Brick.

Supplementing the good information outlining in a general way some of the properties of fireclay brick, it seems that some brief remarks regarding power pressed fireclay brick may be of interest. By this method of manufacture, the clay mixture is formed under high pressure by a vertical stroke so that an exceedingly homogeneous texture entirely free from any laminations is secured. Power pressing by means of a vacuum contributes much to the desirable properties of brick made this way, for certain applications. By means of equipment for de-airing the pugged mixture by the extrusion process from the auger machines, laminations can be materially reduced.

M. J. TERMAN: Mr. Leun has made a valuable contribution to the proper use and application of refractories in the steel plant.

It is interesting to note the growing acceptance of insulating firebrick as standard materials for primary linings in both high and low temperature reheating furnaces.

Representative installations of insulating firebrick for high temperatures include forging furnaces, soaking pit covers, continuous and batch type reheating furnaces.

The lower temperature installations include galvanizing, patenting, sheet normalizing, pack heating, tube type and direct fired annealing covers, tube normalizing, roll annealing and many others.

The use of the low weight—low conductivity insulating firebrick for relatively low temperature uses (up to 2200°F.)are well known as primary furnace

linings. However, their use as effective backing-up insulating brick might well be stressed.

The factor of safety offered by the use of these materials is of considerable importance and appeals to many users. This is a relatively new consideration inasmuch as the older types of insulating materials suitable for backing-up purposes have had a low order of refractoriness, which meant that they had to be used with extreme care. With an increase of the interface temperature (due to wearing away, cracking or spalling of the protective lining) trouble in the form of shrinkage or partial disintegration usually followed.

Insulating firebrick used under similar conditions give a more stable and safer construction. Likewise the original insulating efficiency is maintained and the reclaiming value is higher due to the absnce of shrinkage and structural change.

Heavy alumina-silica refractories fired at temperatures above 2900°F. have found extended uses in hot zones of heavy duty reheating furnaces, soaking pits, and other applications where extremely high temperatures prevail.

DISCUSSION—MODERN REFRACTORIES

BY L. J. TROSTEL

(Continued from page 35)

The successful and economical use of basic brick for glass furnace checkers furnishes some reason for thinking they should be tried in open hearth regenerators but it would seem to me such a move should be preceeded by better designed heat exchangers and perhaps more successful removal of solids from open hearth products of combustion.

Magnesite nozzles and preformed tapping holes of Ritex material are giving satisfaction in scattered applications but in a good many instances, ventures in this direction have not worked out profitably. Perhaps more should be done with magnesite nozzles than is now the case but the user of this material for teeming must unlearn some of the things that are orthodox with clay nozzles.

M. J. CONWAY: Mr. Trostel's paper at least reminds us that the refractory manufacturers are alive to the needs of the Steel industry and that they are trying to help us help ourselves in lowering refractory cost.

Discussing his description of insulating brick, which depend on their cellular structure for their insulating value. Is it possible to obtain this brick with a smooth surface, that is, with practically no cells exposed to the furnace gases?

Would Mr. Trostel recommend washing the surface of the exposed brick after being placed and what should be the composition of the wash he recommends?

L. J. TROSTEL: In answer to Mr. Conway's question, it is not possible with present manufacturing methods to produce insulating firebrick with no cells exposed. This is due to the fact that practically all of these brick before shipment, must be ground to size on all but six faces. Washing the exposed surface after the brick are installed is recommended as good practice to lower permeability to gases. A non-shrinking mortar, with good adhesive properties, to which no alkaline fluxes have been added, is required. The best of this type now available would be a sillimanite cement.

Spring Engineering Conference

BUFFALO, N. Y.

April 28 - 29

Technical Sessions
HOTEL STATLER

Wednesday Evening 7:30 P. M.

Thursday Morning 9:30 A. M.

INSPECTION TRIP
THURSDAY AFTERNOON

New Continuous Hot and Cold Strip Mills

BETHLEHEM STEEL COMPANY

ASSOCIATION ACTIVITIES

CHICAGO DISTRICT SECTION

March 23, 1937

Phil Smidt's Restaurant
1170 Indianapolis Blvd.
Roby, Indiana

Dinner 6:15 P. M.
Meeting 7:45 P. M.

"Cold Strip Mills" by John L. Young, United Engineering & Foundry Company, Pittsburgh, Pa., and A. F. Kenyon, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.

CLEVELAND DISTRICT SECTION

March 29, 1937

Salle Modern Room, Hotel Statler
Cleveland, Ohio

Meeting 8:00 P. M.

Dr. Philip Thomas of the Westinghouse Electric & Manufacturing Company will present a lecture on electronic and light sensitive devices.

PITTSBURGH DISTRICT SECTION

April 1, 1937

Blue Room
Wm. Penn Hotel

Dinner 6:30 P. M.
Meeting 8:00 P. M.

"Modern Switchgear for Steel Mills" by F. E. Fairman, Jr., General Electric Company, Philadelphia, Pa.

SPECIAL FEATURE

Movies of the Strip Tin Mill of the Republic Steel Corp., Niles, Ohio.

SPRING ENGINEERING CONFERENCE

April 28, 29, 1937
Technical Sessions, Statler Hotel, Buffalo, New York
April 29
Inspection Trip to Strip Mill Installations, Bethlehem Steel Company, Lackawanna, New York.

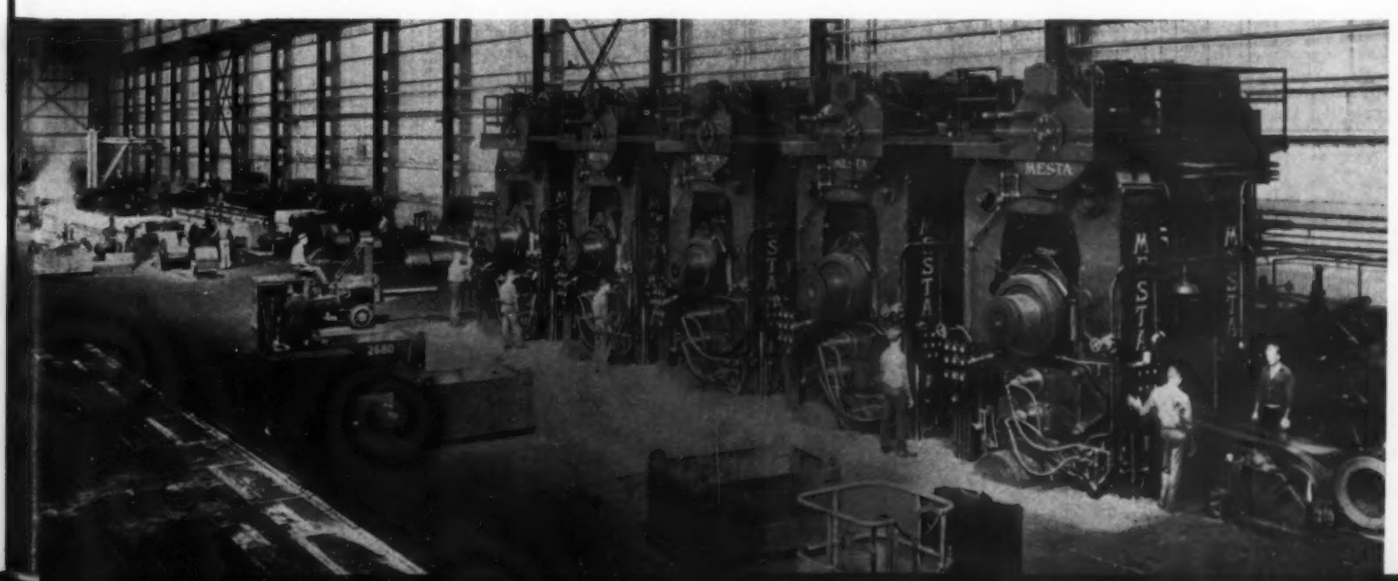
PHILADELPHIA DISTRICT SECTION

April 3, 1937—**INSPECTION TRIP**

The Bethlehem Steel Company has extended to the members of the Association an invitation to visit the New Cold Strip Mill at Sparrows Point, Md.

"Electrical Equipment for Cold Mills" by L. A. Umansky, General Electric Company, Schenectady, N. Y. The presentation of this paper will follow the inspection trip.

Cold reducing tin plate mill, Bethlehem Steel Company, Sparrows Point, Md., to be inspected April 3, 1937.



Carnegie-Illinois

OPENS NEW FURNACE

▲ MORE than two hundred railroad executives and business leaders visited the Gary Works of the Carnegie-Illinois Steel Corporation on March 10 to attend the formal inspection of the new Brunorizing furnace in the plant's rail mill. The new furnace is the result of more than 25 years of research. In it, rails, as delivered from the mill, are given a controlled thermal treatment, resulting in greater ductility and higher resistance to impact. The furnace has a capacity of 70 gross tons of steel rails per hour.

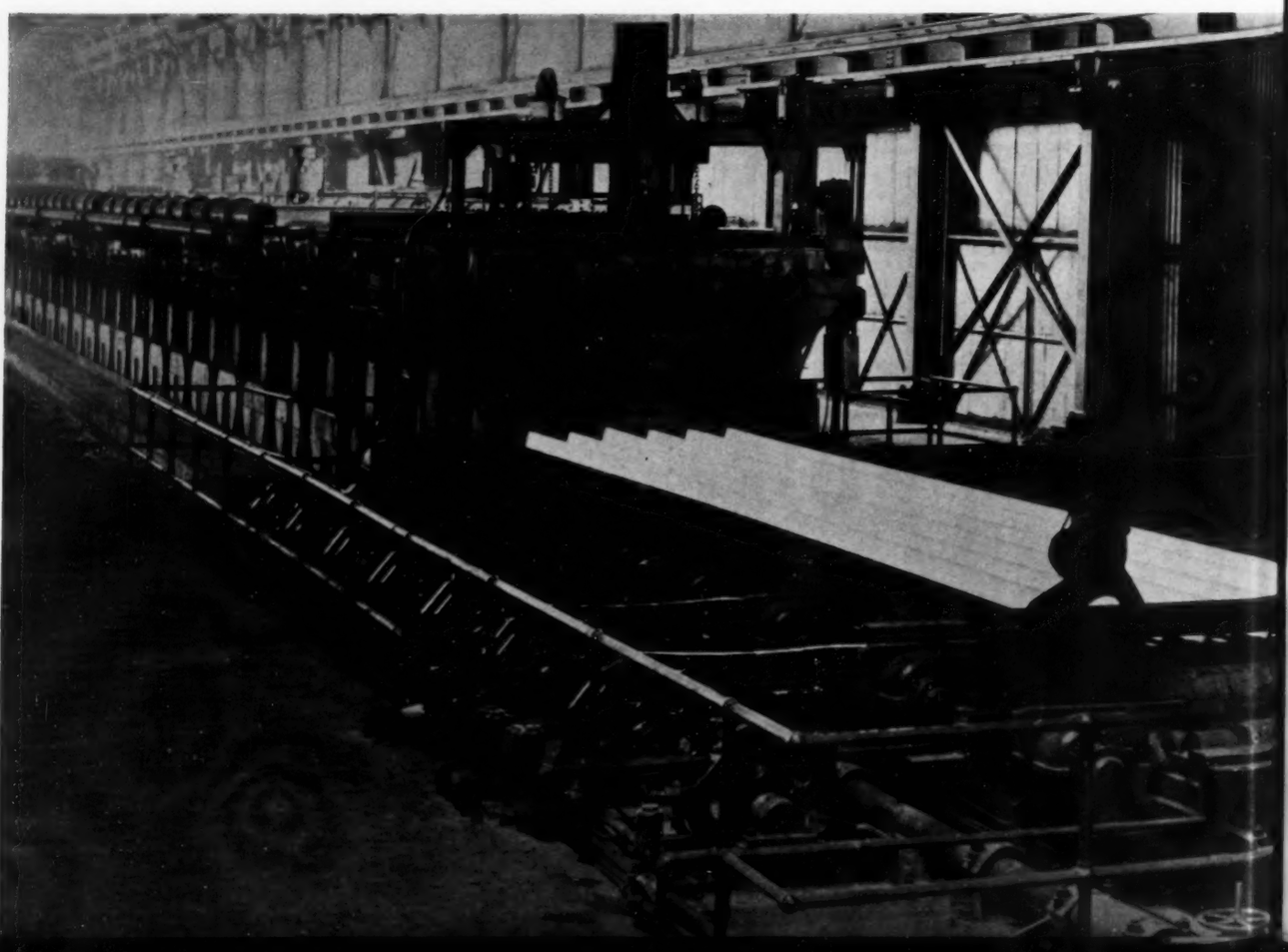
The first of its kind ever installed in the United States in a rail mill, the furnace is 250 feet long and 9½ feet wide. A charge of from five to eight rails enters and another leaves at uniform intervals of from three to five minutes. Each rail in its journey through the eight automatically controlled heating zones remains in the furnace from eighteen to thirty minutes, depending upon the section of rail and the number of rails in the charge. The rails move automatically over specially constructed alloy rollers from zone to zone. This new furnace, together with the method of end-hardening rails by means of jets of compressed air, produces a rail of superior quality, designed to meet the constantly increasing stresses imposed by modern rail traffic. It is the latest step in the modernizing program begun in 1930 in the company's plants in the Chicago area, and carried out throughout the last six years, to keep production and quality abreast with trade requirements.

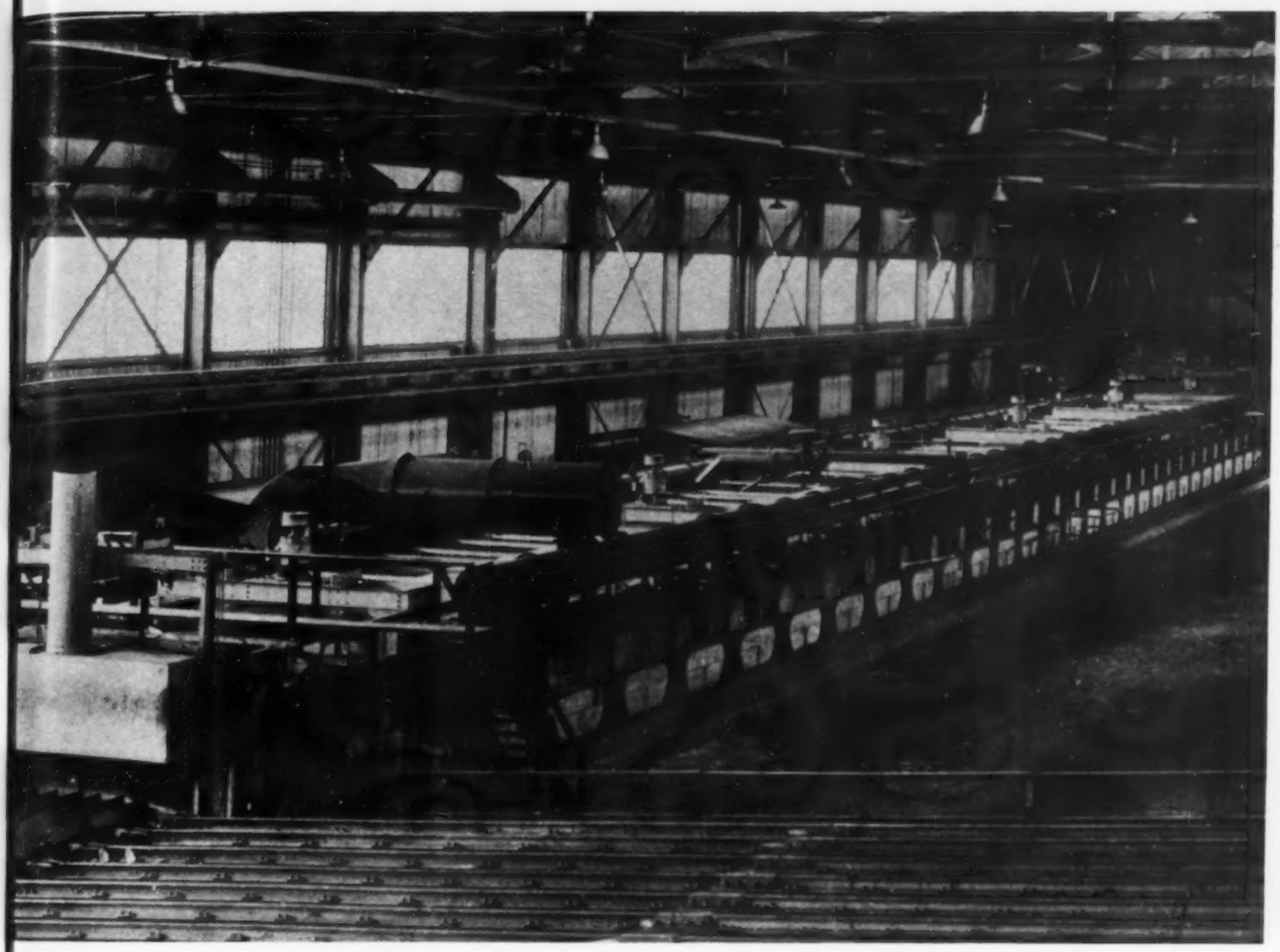
Recent announcement of a large-scale building program at Pittsburgh is another of these steps in the modernizing campaign. It constitutes the second chapter of a development begun at Gary Sheet and Tin Mills of Carnegie-Illinois Steel Corporation and carried on continuously during the depression years.

A second five-stand tandem, cold reduction mill,

A charge of six rails emerging from the new Brunorizing Furnace at the Gary Works of Carnegie-Illinois Steel Corporation, a United States Steel Corporation subsidiary.

These rails, as delivered from the mill, pass through eight automatically controlled heating zones to receive a controlled thermal treatment resulting in greater ductility and higher resistance to impact. This new furnace has a capacity of 70 gross tons of steel rails per hour.





View of the new Brunorizing Furnace at Gary Works of the Carnegie-Illinois Steel Corporation.

which will bring the rated capacity of the company's Gary Tin Mill to 300,000 tons of cold reduced tin plate annually, has been put into operation recently, as one of the improvements in this modernizing campaign.

This new cold reduction mill is similar to one which was placed in service in July, 1936. Combined with two earlier cold reduction units and with the producing old style hot mills still in service, those new mills will give the company a total annual producing capacity of 450,000 tons of tin plate or an average of a million and a half sheets of tin plate daily. Although gigantic in size and output, these mills are capable of producing tin plate down to five-thousandths of an inch in thickness, or one-quarter of the thickness of an ordinary bond paper letterhead.

One of the earliest accomplishments of this modernizing program was the construction during 1930 of what was at that time the world's largest continuous plate mill at the South Works in South Chicago. A four-high continuous plate mill turning out long lengths of light plate in widths up to 87 inches, it was the first of its kind ever built for handling light plate of this width. It marked a great step forward in the technical perfection of steel-finishing equipment, making possible production of steel plate of more uniform gauge with a surface superior to that produced on older style mills. It also makes possible the production of coiled products for cold reduction in widths greater than any previously produced in this grade. Adoption of this type of equipment throughout the steel industry since its installation, by this United States Steel Corporation subsidiary is a definite indication of its value as a pioneering enterprise.

Early in 1935, as the result of a survey of possible markets and plant facilities, the company modernized its facilities for the manufacture of flat strip steel by changing the 28 inch two-high strip mill at the Gary Steel Mill to a 38 inch mill of the four-high type, which meant virtual reconstruction of this mill. This mill now has the capacity to produce 400,000 tons of strip per year. At the Gary Sheet Mills, two new reversing cold reduction mills were completed early in 1935, and a new three-stand tandem cold reduction mill was put into operation in July, 1936. These mills turn out sheet steel of superior accuracy and forming quality which finds wide use in the manufacture of automobile bodies, mechanical refrigerators, steel furniture, washing and ironing machines, sheet steel kitchen stoves and similar products.

In March, 1936, the company placed a new 80 inch continuous hot strip mill in production at the Gary Sheet and Tin Mills. Housed in buildings approximately 300 feet wide by 2,200 feet long, the mill was built on made land on the shore of Lake Michigan. Although its rated capacity is 60,000 tons per month, it has already, on several occasions, exceeded this production rate and has turned out as much as 66,000 tons per month.

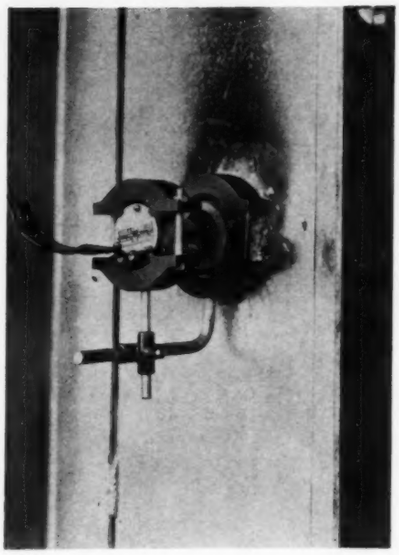
RAYOTUBE RESPONSIVE TEMPERATURE DETECTION

▲ THE costly maintenance of ordinary thermocouples exposed to high temperatures, contaminating gases, and severe vibration is said to be eliminated in plants using a remarkably responsive detector which not only detects continuously the temperature of forge, slab billet and heat-treat furnaces . . . but in some heat-treat shops is actually detecting the temperature of the *work itself* as it drops off a conveyor into the quench.

Offered by Leeds & Northrup, Philadelphia, this detector . . . a Rayotube . . . is available in two models . . . a wide-angle type for large area temperature detection, and a narrow-angle type for temperature detection of smaller areas. Both mount in a safe, "cool" place just outside the furnace . . . and both, according to the maker, hold sensitivity and calibration reliably throughout their entire life even when operating alongside heavy hammers, or in the presence of contaminating gases.

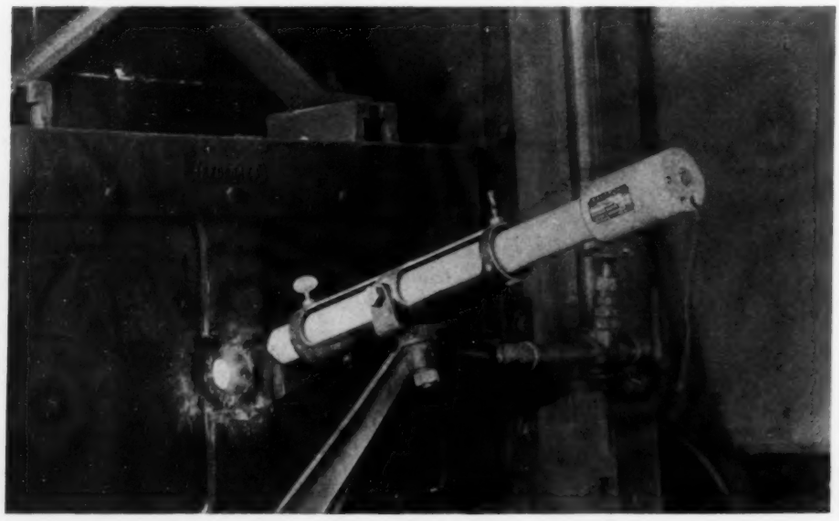
With Rayotube is used a standard Micromax which can continuously indicate and record temperature, and automatically operate signals or controls.

Six new illustrated folders describe the application of Rayotube equipment to quench zones, forge furnaces, high-temperature heat-treat furnaces, controlled-atmosphere heat-treat furnaces, slab and billet furnaces. Copies of any of these publications may be had by addressing Leeds & Northrup Company, 4934 Stenton Avenue, Philadelphia, Penna.



Rayotube mounted on outside wall of furnace.

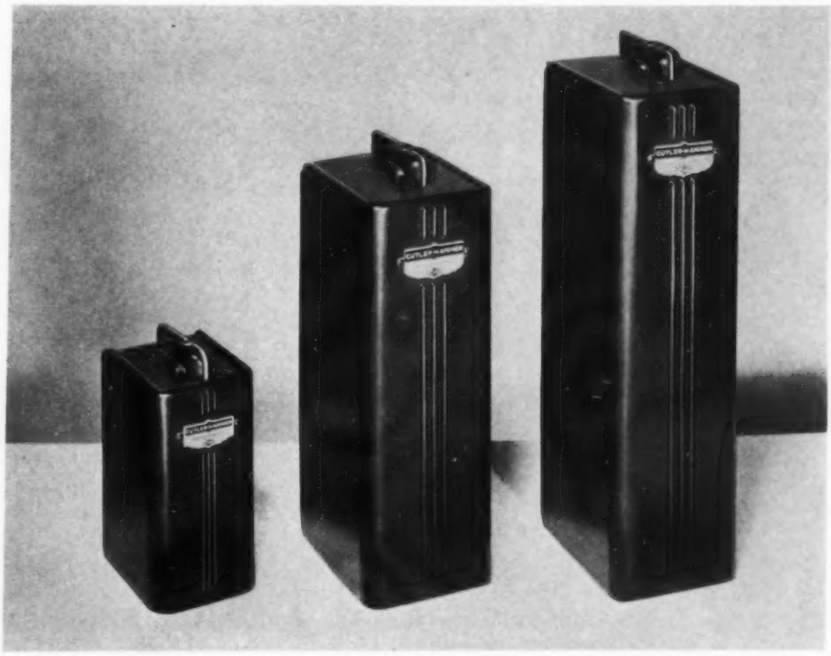
Mounted at discharge end of continuous heat-treat furnace, wide angle Rayotube sights directly on work about to quench.



UNITED AWARDED NEW COLD MILL

▲ THOMAS Steel Company, Warren Ohio has awarded a contract to United Engineering & Foundry Company, Pittsburgh, for a 10″ and 26″ x 24″ four-high single stand reversing cold mill.

FRACTIONAL HORSEPOWER DRUM CONTROLLER



New fractional horsepower drum controllers for reversible A. C. squirrel cage motors.

▲ A NEW line of fractional horsepower drum controllers is announced by Cutler-Hammer, Inc., manufacturers of electric control apparatus, 259 N. 12th Street, Milwaukee, Wisconsin.

They are for use with reversible A. C. squirrel cage motors and reversing or non-reversing multi-speed squirrel cage motors, driving machine tools and similar machines where speed regulation is desired.

An "airstyled" removable case encloses a compact mechanism offering such features as insulated cylinder to which the segments are firmly secured without screws—non-stubbing, renewable contact fingers mounted in individual bakelite mouldings, easily accessible for wiring—positive action, self-indexing drum.

MODERNIZATION AT GREAT LAKES

▲ CONSTRUCTION of an additional blast furnace at the plant of Great Lakes Steel Corporation, Detroit, Mich., has been authorized by the board of directors of National Steel Corporation. Great Lakes Steel Corporation, a unit of National Steel Corporation, is the only integrated steel producer in the Detroit area.

The new furnace will be one of the largest blast furnaces ever built. Construction will be started immediately and it is expected that the furnace will be in operation on December 1, 1937, according to George R. Fink, president of Great Lakes Steel Corporation and also of National Steel Corporation.

The Great Lakes blast furnace plant is located at Delray, Mich., a short distance from the company's main plant at Ecorse. The new furnace will be in addition to the present equipment of the plant which includes two blast furnaces and auxiliary facilities.

Extensive modernization of the blowing and power equipment of the blast furnace plant has just been completed. Through this program, provision has already been made for the additional facilities that will be required by the expansion of operations.

The enlarged blast furnace plant, Mr. Fink said, will supply increased capacity sufficient to provide amply for all hot metal requirements of the company. The molten pig iron produced at the blast furnaces is transported in 110-ton hot metal mixer cars for direct charging into the open hearth furnaces at the steel plant.

EXPLOSION PROOF STARTERS

▲ WESTINGHOUSE explosion proof manual motor starters are particularly adapted for control and protection of single phase and polyphase squirrel cage motors where explosion proof equipment is desired. These inexpensive across-the-line starters provide overload protection by the well known disc thermostat, have quick-make and quick-break toggle type mechanism, have trip free handle are front operating, have long life contacts and corrosion resisting finish on all metal parts.

The starters can be changed from one rating to another by changing heaters. The heater coils may be easily changed without disturbing the trip mechanism. The overload control does not open the circuit on overloads which do not endanger the motor such as heavy starting currents, but opens the circuit after a proper time lag before any damage can be done.

AUTOMATIC OIL CIRCUIT RECLOSERS

▲ A NEW low-current unit has been added to the line of FP-19 automatic oil circuit reclosers, according to an announcement by the General Electric Company. The new recloser has a current rating of four amperes and completes the line which will now operate on currents up to 50 amperes, with voltages from 2200 to 7500.

The FP-19 recloser is normally closed in service. The trip coil is enclosed in a steel casing and receives energy from the fault current which

picks up the armature, starting the movable contact of the interrupting element. The lower or stationary contact is in the bottom of the case and is connected to a lead which runs up through one of the porcelain entrance bushings. The upper (movable) contact is connected to the lower end of the operating coil. A short circuit causes the contacts to open immediately, and the arc drawn in the oil is extinguished by oil-blast action. The butt-type contacts are of substantial construction and automatically compensate for burning caused by repeated operations.

The unit which opens the circuit when a line fault occurs, recloses after a three-second interval. If the fault has not cleared the circuit is reopened. Adjustment can be made for one, two, or three reclosures, with a time interval of three seconds between operations. If the fault is still on the line after the last reclosure, the device locks open. When this occurs it must be reset manually.

The following table gives ratings of complete line:

Rated Current Amperes	Minimum Tripping Current Amperes	Interrupting Rating R.M.S. Amperes
4	15	125
8	30	250
15	45	350
25	70	600
50	140	1200

LUBRICATED PLUG VALVE

▲ A.C.F. FULL area lubricated Plug Valve, as manufactured by the American Car & Foundry Company, is constructed upon sound knowledge and experience, and meets the needs of the steel industry on widly diversified services and their attendant control problems.

This Lubricated Valve is an improved design of plug type valve. It has a straight cylindrical plug fitted into a straight body bore.

Means for the proper distribution of lubricant, over all seating and wear surfaces, are provided. No packing or glands are used; sealing against the atmosphere is obtained by metal seats and lubricant.

Full area lubricated plug valve.

The lubricant system is so designed that excess lubricant pressures are impossible, due to a feature which automatically relieves excess pressure and at the same time visibly indicates that the valve is fully lubricated.

The plug, being cylindrical and coated with lubricant, operates easily and does not stick.

Plug and body seating surfaces are always in contact, separated only by a film of lubricant, which prevents entry of grit between plug and body, and insures tight seating.

Steel mill engineers are recognizing the tremendous possibilities of this design of valve. Quite a large number of nationally known steel mills are now standardized on Full Area Lubricated Plug Valves, the result of a constantly growing recognition of its efficiency in this industry.

This design of valve is being used extensively for service on coke oven gas, natural gas, oil and steam. Fuel lines to open hearth furnaces, soaking pits, and annealing ovens. Also, three-way gas reversing valves.

For services where it is essential to accurately control the flow of liquid or gas, the A.C.F. diamond port opening valve with dial indicator has been found to efficiently serve this purpose.

CONTROLLING FURNACE ATMOSPHERE

▲ THE Brown Instrument Company announces the development of their furnace atmosphere ANALYGRAPH. This instrument has been produced after months of elaborate testing to determine the most important measurable factors in furnace atmospheres. The tests covered both electric and fuel-fired furnaces, two widely differing sources of gas feed, and a wide range of temperatures with varying air/gas ratio adjustments.

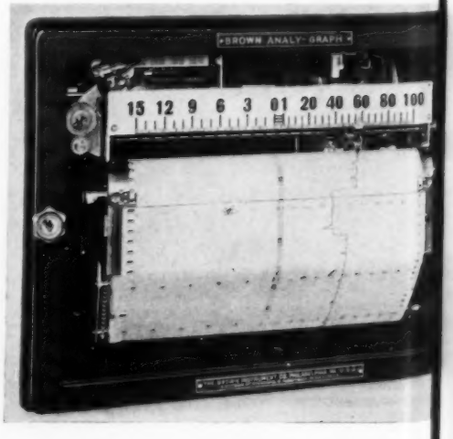
The recording instrument (Fig. 1) is of the potentiometer type and is equipped with a 12″ wide chart graduated so as to render the equipment applicable to measure atmosphere quality whether the said atmosphere results from complete or incomplete combustion, or from dissociation.

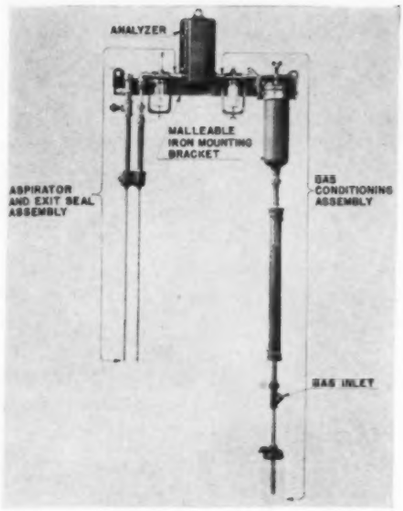
The equipment operates on the principle of measuring the thermal conductivity of the gas mixture, which is continuously drawn from the furnace. Analysis equipment shown in Fig. 2. If the gas is the result of complete combustion, the thermal conductivity will be less than 1.00 due to the presence of CO_2; while if the sample has been produced by incomplete combustion or by dissociation, the thermal conductivity will nearly always be greater than 1.00—the only exception being when there is less than 1% combustible in the final mixture.

In order to render the instrument equally useful for measuring all types

Figure 1

Recording instrument is of the potentiometer type equipped with a 12″ wide chart.





Analysis equipment for furnace atmosphere analy-graph.

Figure 2

of atmospheres, the chart has been divided into two equal sections; one section is used when combustion is complete, while the other is used when combustion is incomplete. This is accomplished by using different electric sensitivities for the Wheatstone bridge through a patented feature.

The furnace atmosphere ANALY-GRAPH meets a long felt need in the heat treating industry, where it is now generally recognized that for best results in preheating, hardening, carburizing, etc., special gas atmospheres must be maintained around the metal. It does away with guess work in establishing the furnace atmosphere and applies potentiometer accuracy to the measurement of furnace atmosphere quality. It is easily maintained—independent of normal variations in furnace pressure, room temperature, and atmosphere humidity. The large scale on the instrument permits operators to continually observe the condition of their furnace atmosphere even at a distance.

In the development of this instrument, a number of actual production runs have been made showing definitely that the brown furnace Atmosphere ANALY-GRAPH presents reliable operation data for the heat treater.

PENCOYD CONTROLLED BY CARNEGIE-ILLINOIS

▲ The Carnegie-Illinois Steel Corp. announced that effective March 1, it will assume control of Pencoyd Plant of the American Bridge Company in Philadelphia and will operate same as a part of its Eastern or Pittsburgh District.

William S. Unger, new Assistant General Superintendent of the Homestead Steel Works will become General Superintendent of the Pencoyd Plant.

The American Bridge Company will retain the bridge shop and erection tool house, but the other operations at Pencoyd became Carnegie-Illinois Steel Corporation properties. Both Companies are Subsidiaries of United States Steel Corporation. The Carnegie-Illinois Steel Corporation Pencoyd Plant will consist of 11 open-hearth furnaces, a 36″ blooming mill, a 12″ bar mill, a 20″ structural mill, and a 23-28″ structural mill, a large machine shop and steel, iron and brass foundries.

A. H. Wartman, who has been Acting Manager at Pencoyd since January 1, 1937, will be Assistant General Superintendent.

FLUID METER CATALOG

▲ A NEW 40-page Catalog "Bailey Fluid Meters for Steam—Liquids—Gases", designated as Bulletin 301, is being distributed by Bailey Meter Company, Cleveland, Ohio, to those interested in flow meters.

This bulletin illustrates the manner in which any desired combination of indicating, recording and integrating features may be combined with a flow mechanism suitable for the measurement of steam, liquids or gases under high, low or medium pressures.

It explains how the powerful, self-contained Ledoux Bell flow mechanism operates to record the rate of flow without requiring an external power source; explains how auxiliary recorders for pressure and temperature may be incorporated to record on the same chart with the record of flow; describes the Bailey Escapement Integrator; describes a wide variety of primary elements and accessories and discusses major installation considerations.

WELD METALS

▲ A COMPREHENSIVE book, entitled "How to Weld 29 Metals", covering the procedure, conditions and materials for welding modern alloys has recently been published by the Westinghouse Electric and Manufacturing Company. Specific data for welding all types of joints with varying thicknesses of metal, such as electrode diameter, welding current, speeds, deposition, etc., are included. Prepared by Chas. H. Jennings, whose experience and exhaustive investigation into the joining of metals have eminently qualified him as an authority on the subject, this book should be of great value to welding operators in simplifying and improving the welding of present day metals and alloys. Copies of the book are available at 50 cents each from any Westinghouse Welding distributor or direct to department 5-N, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Penna.

MERCER WORKS OPENED

▲ THE Carnegie-Illinois Steel Corporation announced that the Mercer Works at Farrell, Pa., will be reconditioned and reopened for operation shortly.

The plant which has not operated for more than two years will be reconditioned at a cost of approximately $100,000.00, and will employ approximately 450 men.

The company announced that former employees will be given preference in the selection of the operating personnel.

Four roughing and five finishing mills will be recommissioned and will have a weekly capacity of approximately 1,000 tons. Products manufactured will be common hot rolled annealed and single pickled sheets.

MERCHANT MILLS AT BALTIMORE

▲ UNDER a contract calling for a mill of unusual refinements, United Engineering & Foundry Company of Pittsburgh has received an order from the Rustless Iron & Steel Company of Baltimore for a new 12″ merchant mill of the three-high type, consisting of seven roll stands and three cropping shears. The mill will be driven by a 700 H.P. motor.

A specially-adaptable mill was required by the Baltimore concern because of the fact that it will be used for rolling various sections of stainless steel, such as rounds, squares, flats, etc.

The mill will be completed in time to be placed in operation in May of this year.

Rustless Iron & Steel Company ordered the mill to supplement existing capacity as the first step in an extensive program to meet the increased demand for stainless steel products from the automotive and allied industries.

H. A. Brassert & Company are consulting engineers for this plant.

CATALOG ON MOTOR-MOUNTED PUMPS

▲ MOTOR-MOUNTED pumps are described in a catalog issued by the De Laval Steam Turbine Co., Trenton, N. J. This term is used to designate a unit consisting of a centrifugal pump mounted directly upon the frame of an electric motor to form a compact, self-aligned unit with only one shaft and two bearings. The unit does not require a special foundation or sub-base, but can be attached to whatever support is most convenient, such as colum, floor, wall or ceiling, and in any position, as upside down or with the shaft vertical. Also, it may be placed upon a hand truck or suspended from a sling, for portable use. Dimensions and other details are given for pumps of capacities from 5 to 1200 gallons per minute and for heads from 10 to 230 ft., as also pipe friction tables and instructions for selecting and installing pump units. The motor may be of the open, splash-proof, totally enclosed, or explosion-proof type, for direct or alternating current.

TRANSMISSION SYSTEM

▲ THE Okonite Company, manufacturers of insulated wires and cables, have developed and patented an entirely new concept of power transmission, which they have named the Oilostatic Transmission System. This system is manufactured by the Okonite-Callender Company of Paterson, New Jersey, a subsidiary of The Okonite Company.

There is available for those who wish a recently published booklet describing this system and two of its installations.

NEW BULLETINS

▲ THE Harnischfeger Corporation, 4400 W. National Avenue, Milwaukee Wisconsin has issued a new bulletin called "P & H Hoists." Profusely illustrated with more than 25 industrial application photographs, the bulletin describes the added advantage in handling "off-the-floor." It contains the treatment of both general and specific problems in the industrial handling field as well as many diagrams which explain simplified construction and operation, together with other vital points in modern hoist design. The bulletin lists the ratings and operating ranges for hoists from the hundred pound capacity to fifteen ton capacity sizes, as well as specifications and electrical accessories. Copies may be had upon application to the company's agent and representative, or to the factory directly. Ask for Bulletin No. H-5.

▲

▲ THE Roller-Smith Company, 233 Broadway, New York City, announes Broadway, New York City, announces a new Catalog covering a new device, the "Hipot" Insulator Tester.

A copy of Catalog 11, Section 2 covering this apparatus is available.

NEW CATALOGS

▲ IN view of the present wide use of pulverized-coal firing for power boilers and other applications, a new booklet, the B & W Direct-Firing Pulverized-Coal System, just issued by The Babcock & Wilcox Company, should be of interest. It is a presentation not merely of B & W Equipment but of the direct-firing pulverized-coal system from bin to burners.

The advantages of the B & W Direct-Firing System in reliability, efficiency, ease of operation, and safety are clearly stated. Such important features of the well-known Type B Pulverizer as sustained high fineness and capacity, low maintenance, and reliability are also presented. The booklet also contains considerable useful engineering information.

Copies of the booklet may be had on application to The Babcock & Wilcox Company, 85 Liberty Street, New York, N. Y.

▲

▲ COMBUSTION Engineering Company, Inc., New York, has just issued another of its series of equipment catalogs. This covers its extensive line of CE bent-tube boilers, many pages being devoted to cross-sections of typical installations of various types, in addition to descriptive matter, photographs of furnace and boiler details, and shop views showing the fabrication of high-pressure, fusion-welded drums from the bending of the plate to the finished product, including X-ray examinations. The catalog is printed in two colors and is attractively illustrated.

▲

▲ R. E. UPTEGRAFF Manufacturing Company, Pittsburgh, have just issued a new book on Distribution Transformers, Catalog No. 105. The illustrations go through the various phases of transformer manufacture, show cut-away models, and the book gives tables of voltage ratings, of accessories, and of prices. A copy of the Uptegraff Distribution Transformer catalog may be had by addressing the manufacturer at 328 North Lexington Ave., Pittsburgh, Pa.

Items of Interest

Nathaniel B. Randolph, as was mentioned in this magazine's last issue, has been made Vice-President in Charge of Sales of the Granite City Steel Company, upon the resignation of Mr. L. F. Miller. Mr. Randolph entered the steel industry in the sales capacity following his graduation from Virginia Preparatory School. He was first associated with the Granite City Steel Company in 1919. Subsequently he was appointed to District Manager in 1921 and advanced to Assistant General Manager of Sales in 1933.

▲

Byron B. Johnston, whose new appointment as Assistant General Superintendent of the Granite City Steel Company, was mentioned in last month's issue first entered this Company's employ in a clerical capacity. In 1930 he was made Assistant to the General Superintendent.

▲

B. M. Livezey, as announced by the Carnegie-Illinois Steel Corporation, has been appointed as assistant to the manager of operations, Chicago district. Mr. Livezey has been assistant general superintendent of the company's Clairton steel works and coke plant up to the present time.

Mr. Livezey has been associated with the company, a United States Steel Corporation subsidiary, since 1916, when he graduated from Lafayette College with a degree in Chemical Engineering. He was made assistant general superintendent at Clairton in charge of the coke by-products plant, on August 1, 1936.

▲

The Carnegie-Illinois Steel Corporation announced recently the following appointments:

Thomas A. Brown, assistant manager of industrial relations, Pittsburgh District.

L. P. Ray, superintendent of industrial relations, Farrell Steel Works and Central Furnaces.

Charles Magnani, assistant to chief industrial engineer.

Brown, 30 years of age, came to the industrial relations department, of which Ross L. Leffler is manager for the Pittsburgh District, from the industrial engineering department. He was chief industrial engineer of the American Sheet and Tin Plate Company from May 1, 1934, until that company merged with Carnegie-Illinois in June, 1936. He had been employed three years prior to that time in the industrial engineering department of the former Carnegie Steel Company.

Ray moved up to the newly created position of superintendent of industrial relations at the Farrell Works, which includes under its jurisdiction the blast furnace plant at Cleveland, Ohio, from the post of management representative and assistant chief clerk at Farrell. He has been in continuous service of the company since 1893, starting as a messenger boy for the Sharon Iron Company, which later was merged with the United States Steel Corporation.

Magnani, as assistant to J. A. Hagan, chief industrial engineer of the company, began his service with the United States Steel Corporation subsidiaries in 1916 as a stenographer for the American Steel and Wire Company. As a member of the Steel Corporation's Power Investigating Committee he worked successively in the plants of the Steel and Wire Company, The National Tube Company, and the American Sheet and Tin Plate Company. He went to the Carnegie Steel Company's Duquesne Works in 1933 as the plant industrial engineer and held that position prior to his new appointment.

NATHANIEL B. RANDOLPH

BYRON B. JOHNSTON

B. M. LIVEZEY

ALFRED E. GIBSON

J. HARRY WARRINER

W. A. WATSON

Alfred E. Gibson has been elected President of The Wellman Engineering Company, Cleveland, Ohio, succeeding Mr. George W. Burrell who becomes Chairman of the Board.

Mr. Gibson first worked for the Company during summer vacations when in College, and upon his graduation in 1909 from Ohio State University, he entered the employ of the Company in its operating department, later becoming superintendent of its Cleveland plant, then general superintendent in charge of both its Cleveland and Akron, Ohio plants.

In 1926 he left Wellman and became associated with the Fulton Foundry & Machine Co., Cleveland, Ohio, as vice president, later being elected president.

In 1928, upon the election of George W. Burrell as President of The Wellman Engineering Company, Mr. Gibson returned to the Wellman Company as its works manager. In 1930 he was elected vice president and in 1931 vice president and assistant general manager in charge of engineering and shop production, and in 1935 was appointed executive vice president and now becomes its president. The Wellman Company, under Gibson's direction, has widely extended the use of the welding processes and made extensive applications of the new low-alloy, high strength steels, to its engineered products.

Mr. Gibson is president of the American Welding Society; a member of the American Society of mechanical engineers; the Association of Iron & Steel Engineers; the Society for Metals; the International Acetylene Association.

▲

J. Harry Warriner has been appointed works manager of The Wellman Engineering Company, Cleveland, Ohio.

Mr. Warriner started working for the Wellman Company in 1905 as tool-room boy, afterwards serving an apprenticeship as machinist, and later becoming its shop estimator.

In 1919 he was placed in charge of production and estimating at the Company's Akron, Ohio, plant.

In 1925 he returned to Cleveland, having been promoted to the sales department and assigned to special sales work, and served in this position to the time of his recent appointment as works manager.

"Harry", as Mr. Warriner is familiarly, and well known to the industry, has a record of 32 years of continuous service with The Wellman Engineering Company.

▲

W. A. Watson has resigned the Vice-Presidency of the Stowe-Fuller Refractories Company and has organized the Midwest Refractories Company, with offices at 627 Union Trust Building, Cleveland, Ohio. This Company will market a general line of refractories in the territory west of Pittsburgh. Mr. Watson is well known to the steel fraternity as he has been engaged in contacting this industry for many years.

▲

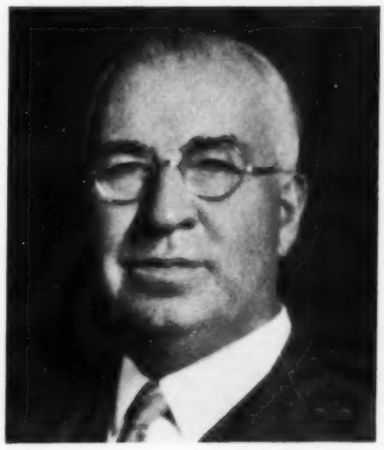
WANTED: Young engineering school graduates of outstanding character and excellent personality to train for field work as Sales Engineers for well known manufacturer of industrial instruments and automatic control equipment. Candidates preferred who have had some industrial plant or public utilities experience and are under thirty and now free for quick transfers and extensive travel. Unusual opportunities for promotions. Write stating age, education, experience and salary desired.

▲

ENGINEER WANTED: A leading British Manufacturer of heavy machinery requires at once an engineer, experienced in the design and arrangement of modern heavy duty Rolling Mill equipment, to act as Chief Engineer of its Rolling Mill department. Write, stating age, education, experience and salary desired. Applications regarded confidentially if desired. Address MAC, 1010 Empire Building, Pittsburgh, Pa.

ADVERTISING PAGES REMOVED

C. W. Heppenstall, President and Treasurer of the Company bearing this name was honored February 15th at a dinner given by the employees. Mr. Heppenstall is of the fourth generation of Heppenstall steel men, whose name has been associated with the progress of steel in England and America for 145 continuous years. He entered the steel mill field at the age of fourteen and through the years worked his way up to the high position he now occupies.



C. W. HEPPENSTALL

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John H. Elliott has been appointed assistant general superintendent at the Shenango Works of the Carnegie-Illinois Corporation.

Mr. Elliott came to Shenango Works in 1926, as combustion engineer. He was made superintendent of the annealing department in 1932, and last August was named acting master mechanic. He entered the employ of the American Sheet and Tin Plate Company at Pittsburgh in 1919, in the engineering department.

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The Association of Iron & Steel Engineers regret to announce the resignation of John Kelly, Jr., which became effective March 3, 1937.

Mr. Kelly was affiliated with the Association for several years in the capacity of Associate editor of the Iron & Steel Engineer and was also active in connection with the annual convention and exposition of the Association.

▲

Noble Jones, for the past fifteen years connected with the Allegheny Steel Company at its West Leechburg, Pa., plant, has been appointed general manager, Barium Stainless Steel Corporation, Canton, Ohio.

Leo. F. Worden, Industrial Control Specialist with the General Electric Company, Pittsburgh Office, was one of thirty-three employees honored by his Company for an outstanding achievement in 1936. The award was granted for Mr. Worden's suggestion of making steel mill control completely assembled in the factory. This idea has been recognized by Steel operators as a distinct advancement in the trade.

LEO F. WORDEN

Mr. Worden has been working in the Pittsburgh district for the past eight years.

▲

J. R. Hoover, for the past six years assistant manager of chemical sales, mechanical rubber goods division, B. F. Goodrich Company, Akron, Ohio, has recently been made manager of that department. He takes over the duties of Dr. H. E. Fritz who will devote his efforts to the sale and development of a new synthetic elastic material recently introduced by Goodrich.

▲

Charles S. Payson, of New York, has been elected a Director of The American Rolling Mill Company, George M. Verity, Chairman of the Board, announced.

Mr. Payson, who is in the finance and management business, and who is publisher of "The Commentator" magazine, is a director of the Rustless Iron Corporation of Baltimore. It was from him that The American Rolling Mill Company recently acquired a substantial part of its holdings in the Rustless Iron Corporation.

He is also a director of the Marine Midland Corporation.

BROWN PRESENTS

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